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THE ROYAL SOCIETY OF VICTORIA

Volume 118

NUMBER 1

SECOND SPECIMEN OF THE LOWER ACTINOPTERYGIAN *NOVOGONATODUS KASANTSEVAE* LONG 1988 FROM THE EARLY CARBONIFEROUS OF MANSFIELD, VICTORIA.

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HOLLAND, T. M., LONG, J. A., WARREN, A. & GARVEY, J. M., 2004: Second specimen of the lower actinopterygian *Novogonatodus kasantsevae* Long 1988 from the Early Carboniferous of Mansfield, Victoria. *Proceedings of the Royal Society of Victoria* 118 (1): 1–10. ISSN 0035-9211.

A new specimen of the Early Carboniferous actinopterygian *Novogonatodus kasantsevae* Long 1988 from the Snowy Plains Formation, Mansfield Basin, Victoria is described. Previously undescribed elements of the skull, both dorsal and anterior to the orbit, as well as dorsal ridge scales, are shown for the first time. *Novogonatodus kasantsevae* shows many plesiomorphic characters, including an elongated T-shaped dermosphenotic, contact between the nasals and dermosphenotics, a small quadratojugal and three extrascapular bones. Apomorphies present include small postparietals and lack of intertemporals and supratemporals. The previous assignment to the Family Gonatodidae Gardiner 1967 is no longer supported as most of the characters defining the family are widespread features developed within several lineages of basal actinopterygians. Hence, *Novogonatodus kasantsevae* is regarded as a plesiomorphic actinopterygian more derived in the scheme of Cloutier and Arratia (2004a) than the clade containing *Melanecta, Limnomis* and *Howqualepis* (and possibly *Mansfieldiscus*) but less derived than the Aesopichthyidae, Rhadinichthyidae and other crownward Actinopterygii.

Keywords: *Novogonatodus*, Carboniferous, Mansfield, Victoria, Actinopterygii

'PALAEONISCOID' fish from the Mansfield Basin of Victoria, Australia, were initially recognised by McCoy (1890). A Carboniferous age was placed on the fauna by Woodward (1906), who assigned the undescribed '*Cosmolepides sweeti*' (McCoy 1890) to the Northern Hemisphere genus *Elonichthys* Giebel 1848. A second species, *Elonichthys gibbus*, was described from the Mansfield Basin (Woodward 1906). The redefinition of the *Elonichthys* genus by Moy-Thomas & Dyne (1938) and Gardiner (1963) separated the Mansfield palaeoniscoids on the basis of the possession of an accessory ventral bone to the opercular series and the absence of supraorbitals (Long 1988). For this reason the specimens were redescribed by Long (1988) who erected *Mansfieldiscus*, which he removed from the Order Elonichthyiformes (Kazantseva-Selezneva 1977), placing them as Palaeonisciformes *incertae sedis*. A second genus of Mansfield palaeoniscoid, *Novogonatodus kasantsevae* was described by Long (1988) as *N. kasantsevae*, based on a single specimen from the Museum of Victoria, presumably unrecognised as distinct from *Elonichthys* by Woodward. Long (1988) distinguished *Novogonatodus kasantsevae* from *Mansfieldiscus*, placing it in the Family Gonatodidae, at that time distinguished especially by a short deep postorbital blade of the maxilla and a near to vertical suspensorium. Recent phylogenetic analyses of actinopterygian fish (e.g. Cloutier & Arratia 2004a) have shown the former Gonatodidae to be paraphyletic, so that the presence of a deep maxilla is homoplastic. Palaeonisciformes as a whole also have been shown to be a paraphyletic group (e.g. Cloutier & Arratia 2004a; Gardiner et al. 2005) with former members of the group referred to as lower actinopterygians.

Throughout Australia Carboniferous actinopterygians are poorly known. Only indeterminate species are reported from other localities, all of which are from Queensland. '*Palaeoniscum*' *randsi* was reported from the Carboniferous Beds near Boguntungan, Queensland by Etheridge (1892) but as the head is missing the specimen is generically indeterminate (Long 1991). Similarly Turner (1982) recorded *?Elonichthys* sp. from Queensland which was redescribed by Turner and Long (1988) as generically indeterminate. Isolated scales and bones of actinopterygians are known from the Early Carboniferous Raymond Formation, and the mid-Viséan Ducabrook Formation but no identification has been made on this material. To date the Mansfield fish fauna is the only assemblage of well-described Carboniferous actinopteryians from the continent.

The part and counterpart of a lower actinopterygian (NMV P216859, Fig. 1) was found *in situ* by

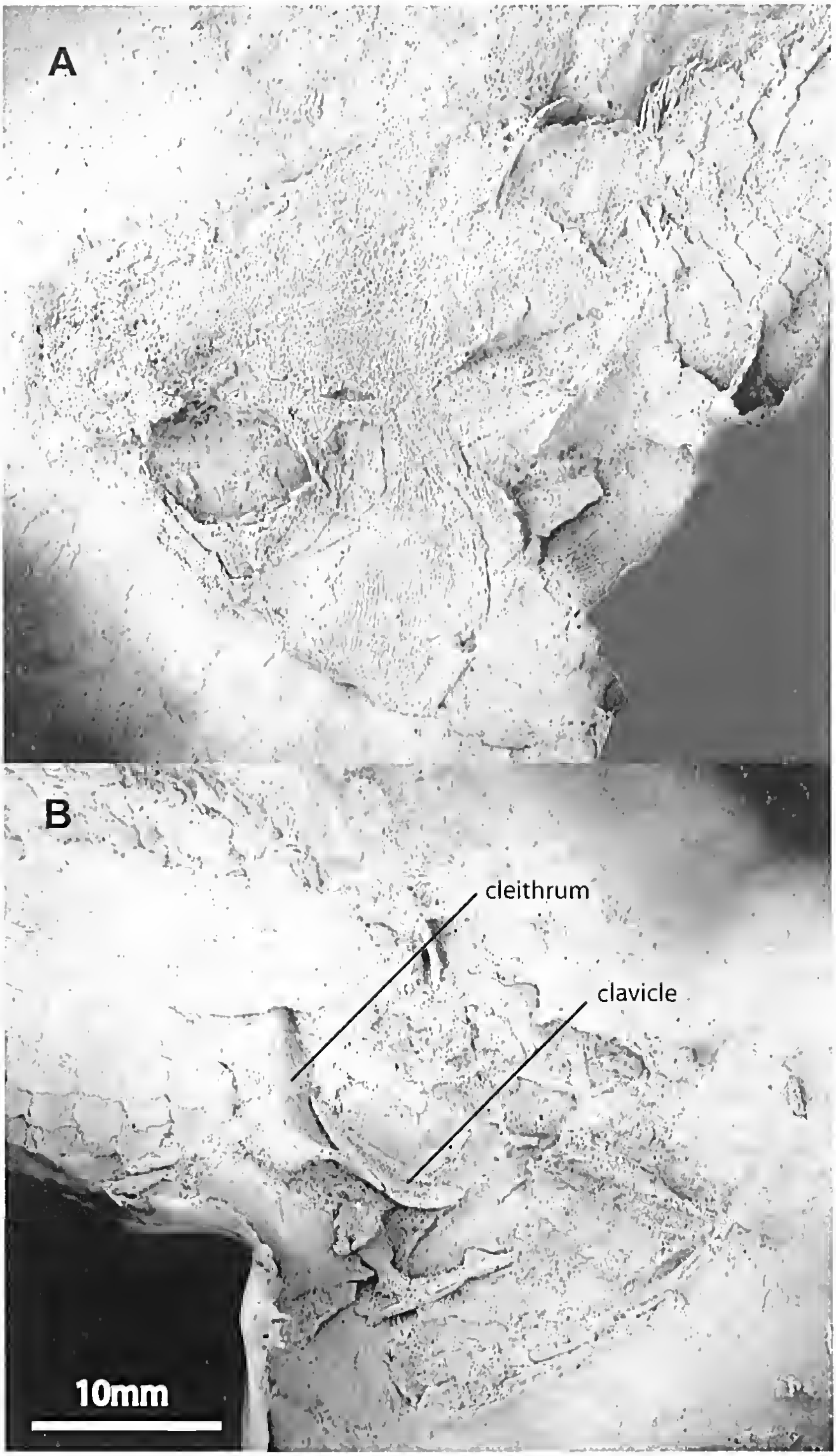

Fig. 1. *Novogonatodus kasantsevae* Long 1988, NMV P216859. **A**, dorsolateral; **B**, ventrolateral views. Photographs of latex mould whitened with ammonium chloride.

A. W. and J. G. in 2002, near the intersection of Bridge Creek and the Broken River, Mansfield Basin, Victoria, downstream from a locality known as Fish Hill (=Tannery Paddock), in the Home Station Sandstone Member, of the Snowy Plains Formation, Mansfield Group (F. VandenBerg et al. 2006). It may be the same locality as the *Mansfieldiscus* specimens and is the presumed locality of the holotype of *Novogonatodus kasantsevae*.

The specimen was initially photographed with a Nikkon Coolpix 995 digital camera, and then etched in 15–20% hydrochloric acid for 24 hours, dissolving much of the bone. The resultant surface of the part and counterpart were cast, first with silicone rubber, and subsequently with black latex. The white silicone rubber was dusted with carborundum powder, while the back latex was dusted with ammonium chloride, and the casts rephotographed.

This paper describes the new actinopterygian as a second specimen of *Novogonatodus kasantsevae*. NMV P216859 preserves parts of the skull that are absent in the holotype, especially above and anterior to the orbit. The skull is only partially distorted so that both sides of the skull roof are exposed in an articulated state, as well as most of the left orbit, cheek, and dorsal operculogular series. The displaced left cleithrum can be seen situated over the opercular series, as are the articulated right cleithrum and clavicle, and the anterior portion of the trunk. The dorsal ridge scales are also well preserved. The new specimen adds significant new information that contributes towards the resolution of basal actinopterygian phylogeny. Some confusion exists in the nomenclature concerning particular bones of the skull of fossil fish (e.g. Poplin 2004) and, as preference for one or other choice of terminology is based on opinions founded upon historical points of view or proposed homology of bones with those of tetrapods, we prefer here to follow the latter, following Dietze (1999).

SYSTEMATIC PALAEONTOLOGY

ACTINOPTERYGII Klein, 1885

Genus *Novogonatodus* Long 1988

Type and only species *Novogonatodus kasantsevae* Long 1988: 47–49.

New material. NMV P216859, a partial skull and anterior trunk (Figs 1–4).

Amended diagnosis. A combination of the following characters distinguishes *Novogonatodus kasantsevae* from other basal actinopterygian taxa: head length 1/5 that of body length; maxillary postorbital blade is deep and short, and as deep as long; preopercular posteroventrally vertical; single dermohyal; small quadratojugal; rostral bone longer than parietal bones; dermosphenotic T-shaped with elongate posterodorsal flange; spiracular slit present in skull roof; three extrascapular bones; infraorbitals comprising small lachrymal, large jugal and three interconnected suborbitals; pelvic fin nearer to anal fin than pectoral; dorsal fin slightly subanterior to anal fin; anterior flank scales (= areas A, B of Trinajstic 1999) square to rectangular broad with thick horizontal and transverse ornament, serrated posteriorly; dorsal (area E) scales diamond shaped; dorsal ridge scales larger, rounded, posteriorly serrated; holotype scale count as follows: 9 rows to pelvic fin, 19 rows to anal fin, 26 rows to dorsal fin, 30 rows to anterior extent of caudal peduncle; 18 rows in one midbody scale row; ridge scales found dorsally along trunk and ventrally as far anteriorly as pelvic fins (Long 1988).

Novogonatodus kasantsevae differs from *Paramblypterus* (Dietze 1999; 2000), the only other Carboniferous actinopterygian with a short, deep maxilla, fusiform body, steeply inclined preoperculars, and large operculars in the phylogenetic analysis of Cloutier and Arratia (2004a), as follows. *Novogonatodus kasantsevae* lacks supraorbitals (or a bone formed by fusion of the supra- and preorbitals), a supratemporal, has a single large dermosphenotic, a single dermohyal, two lateral extrascapulars and ornamented dorsal ridge scales.

Locality of new material. Intersection of the Broken River and Bridge Creek, Mansfield, Victoria (37°011'S, 146°224'E), Home Station Sandstone Member, Snowy Plains Formation, Mansfield Group, Avon Supergroup, Mansfield Basin.

Revision of the geology (Vandenburg et al. 2006) suggests that the Home Station Sandstone lies well above the Devonian-Carboniferous boundary.

Description. The following description emphasises parts of the anatomy of (NMV P216859) not preserved in the holotype (NMV P160862). The left side of the specimen is described unless otherwise noted. The dentigerous snout bones are absent from both specimens so the configuration of premaxilla or antorbitals is not known.

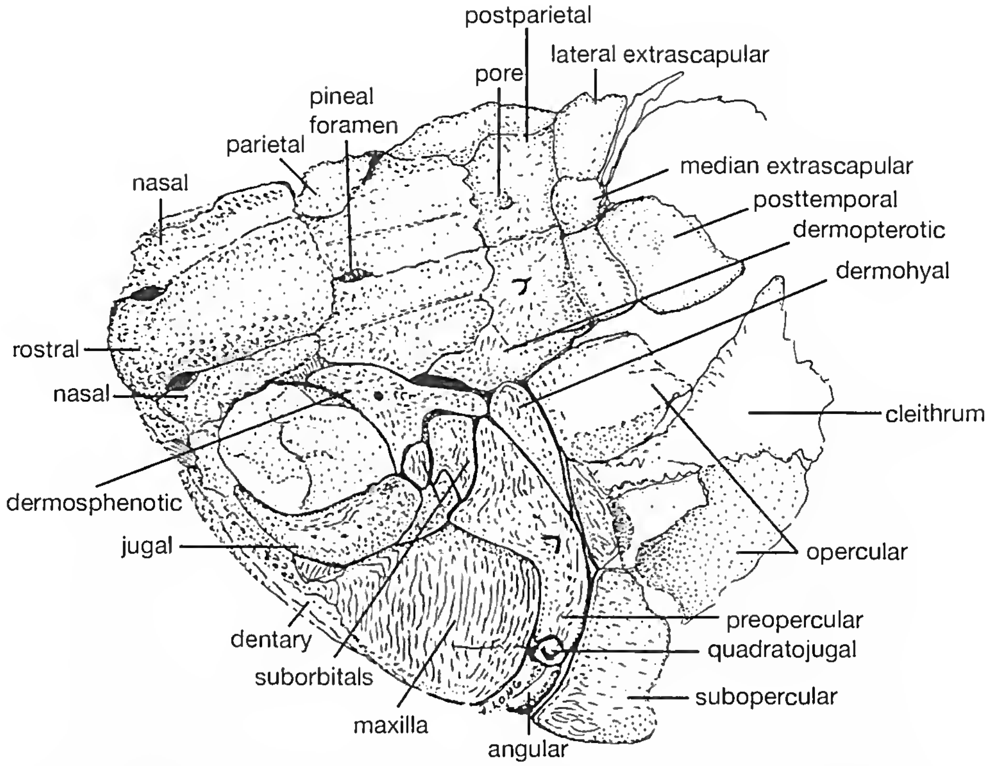

Fig. 2. *Novogonatodus kasantsevae* NMV P216859 Long 1988, in dorsolateral view showing main features of skull and trunk.

The dermosphenotic, located posterodorsally to the orbit, is complete on the left side of the specimen (Figs 1A, 2, 4), showing an elongated posterior flange that was only partially preserved in the holotype, and a single well-defined circular sensory-line pit. The flange contains straight to wavy ornament running anterodorsally to ventroposteriorly. The dermosphenotic is deepest in its posterior half. The circular pit-line pore is a feature also noted in *Howqualepis* where a series of 3–4 such pits are well defined (e.g. Long 1988, fig. 11B). An elongate spiracle is located dorsally to the dermosphenotic and is just under half its length. Three suborbital bones are clustered posteroventrally to the dermosphenotic, comprising two large, irregularly interlocked posterior bones and a smaller subrectangular anterior element about half the size of the other two. Paired nasal bones are located anterior to the parietals and ventrally to the rostral, with a discernable posterior narial notch anterior to the orbit. The dermosphenotics meet the nasal bones along a short anterior suture. A large rostral bone anterior to the parietals is elongated, approximately three times as long as wide and is anteriorly rounded. Its anteroventral margin is marked by one anterior narial opening on each side. Each parietal is approximately equal in width to the rostral and three quarters the length. The parietals are separated by a raised dorsal midline that contains the faint outline of the pineal foramen in its anterior portion. The supraorbital sensory-line canal line runs from anterior to posterior of each parietal and continues onto the postparietals. Each postparietal is approximately equal in width to the parietal but only half the length, making them short and rectangular. Both postparietals contain well-defined v-shaped pit-line grooves for the anterior and middle pit-lines. A short subrectangular medial extrascapular sits posterior to the postparietal bones. It is rectangular, broader than deep and is approximately the size of the dorsal suborbital. Broad lateral extrascapular bones border the medial extrascapular, and laterally overlap the anterior portion of the posttemporal bone. The depth of each lateral extrascapular is twice that of the medial extrascapular

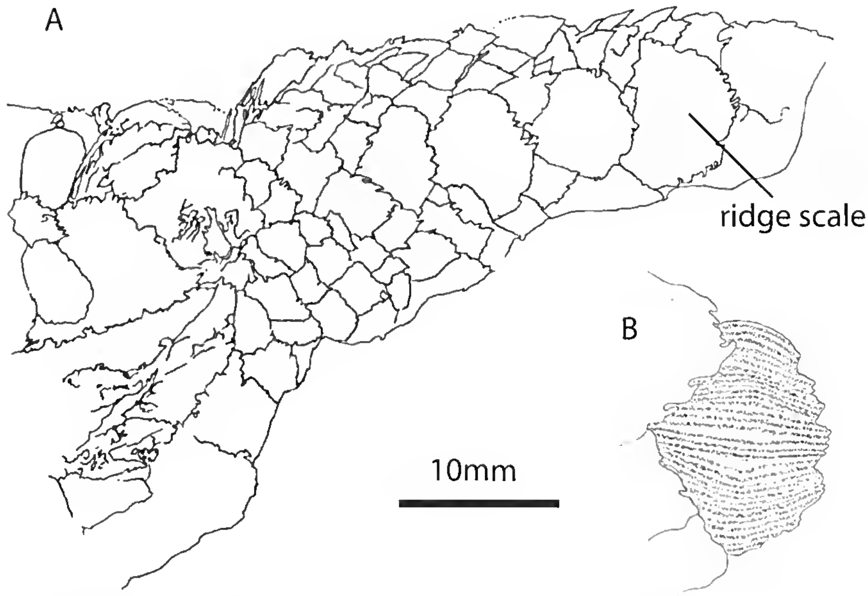

Fig. 3. *Novogonatodus kasantsevae* NMV P216859 Long 1988. **A**, drawing of posterior part of skull and preserved scales in dorsolateral view (note enlarged ridge scales); **B**, composite drawing of a single ridge scale.

bone. Ornamentation on the extrascapular bones is oblique dorsoanteriorly to ventroposteriorly. The left posttemporal is large, ovoid, and lies posterior to the left lateral extrascapular. It is approximately as broad as long. The ornamentation on the posttemporal appears concave around its borders but transverse medially. A small quatratojugal, which was absent in the holotype, is located posterior to the maxilla and ventrally to the preopercular. It contains a pore indicating the presence of a pit line. It is approximately the same size as the anterior suborbital.

The rostral, parietal and postparietals are marked by pustular ornament, in contrast to the other bones that have ridged ornament.

Both part and counterpart of NMV P216859 contain displaced cleithra, with the right articulated with a clavicle (Fig. 1B). The clavicle is elongate and curved, being approximately one third the length of the cleithrum. It shows no special features compared with the cleithra of other Carboniferous actinopterygians (e.g. *Frederichthys*, Coates 1993; *Mansfieldiscus*, Long 1988).

The dorsal midline preserves five ridge scales (Figs 1, 3). Each ridge scale displays an elevated midline, with each side sloping down in bilateral symmetry. The posterior margin of each ridge scale overlaps the anterior portion of the succeeding ridge scale down the body. Ridge scales appear elongated in breadth relative to depth, and are approximately double the area of anterior flank scales. Ridge scale ornamentation is largely convex on either side, curving inwards. Ornament appears wavy closer towards the centre and eventually becomes straight along the midline. The posterior margin of each ridge scale contains numerous serrations, each one representing the end of a ridge of ornament.

Other dermal bones preserved but described in the holotype include the opercular, subopercular, preopercular, and possibly a dorsal edge of the dentary. Numerous anterior flank scales and anterior dorsal scales are preserved in NMV P216859 but were described in the holotype (Long 1988).

Discussion. As in other basal actinopterygians found in the Early Carboniferous, *Novogonatodus kasantsevae* contains many primitive characters and few apomorphies (Fig. 4). The dermosphenotic is elongate and 'T-shaped' with a posterodorsal flange, a feature thought to be plesiomorphic by some workers (Long 1988; Gardiner & Schaeffer 1989; Cloutier & Arratia 2004a; Gardiner et al. 2005) but alternatively considered derived by Schultze & Cumbaa (2001). The presence of an elongated T-shaped dermosphenotic that extends rostrocaudally as far posterior to the orbit as it extends around the orbit is clearly a primitive feature seen in *Cheirolepis* spp.

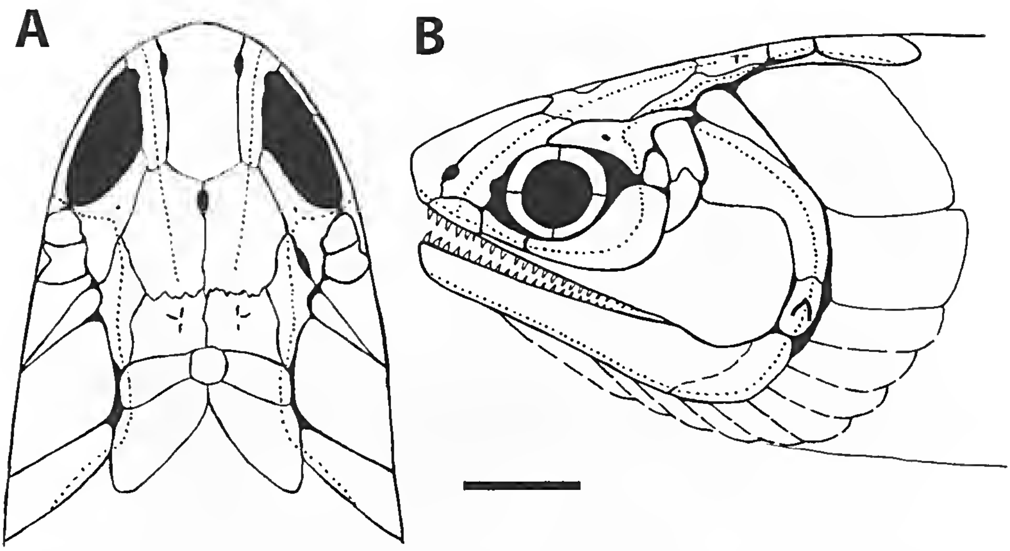

Fig. 4. Reconstructions of *Novogonatodus kasantsevae* NMV P216859 Long 1988. **A**, dorsal and **B**, lateral views. Note that A was drawn normal to the parietal bones. Note that the premaxilla and lacrymal bones are missing from the material but have been drawn in based on surrounding margins of neighbouring bones.

and *Howqualepis* (Gardiner & Schaeffer 1989; Cloutier & Arratia 2004b). The 'T-shaped' dermosphenotic in *Novogonatodus* is seen as part of a more derived character suite relating to the overall skull roof table by the absence of an associated intertemporal and supratemporal bones (Gardiner & Schaeffer 1989; Gardiner et al. 2005). Intertemporal loss apparently transpired by either fusion to the supratemporal or the dermosphenotic (Dietze 2000), although Poplin (2004) also considered that this bone may be divided into two seperate elements, or linked to the dermopterotic in some derived cases. The contact between the dermosphenotics and the nasals in NMV P216859 is regarded as plesiomorphic (Gardiner et al. 2005). This would place *Novogonatodus kasantsevae* as being plesiomorphic with respect to the size of the dermosphenotic but more derived than other taxa bearing such a large dermosphenotic due to the loss of the intertemporal. The presence of a quadratojugal on NMV P216859 is regarded as plesiomorphic, being present in a number of lower actinopterygians (e.g. *Cheirolepis trailli, Howqualepis, Mimia, Moythomasia*: Pearson & Westoll 1979; Gardiner 1984; Long 1988). It is variably developed within genera, as it is present in one species (*C. trailli*) but absent in two other species (*C. canadensis, C. schultzei*; Cloutier & Arratia 2004b). Its small size is considered primitive (Cloutier & Arratia 2004a), and this is again symplesiomorphic with *Paramblypterus* (Dietze 1999).

Few apomophies are found in *Novogonatodus*. Short and rectangular postparietals, being smaller in size than the parietals, are considered derived (Cloutier & Arratia 2004a). Three extrascapular bones, as in *Paramblypterus* (Dietze 1999) are found in *Novogonatodus*, a state regarded as plesiomorphic by Lund et al. (1995) using sarcopterygians as an outgroup. However we note that in the most primitive known actinopterygians, paired extrascapulars are found (*Cheirolepis* and *Howqualepis*; Pearson & Westoll 1979; Arratia & Cloutier 1996; Long 1988), so the presence of three or more extrascapulars is here considered to be derived within the Actinopterygii as in *Kalops* (Poplin & Lund 2002) and in Rhadinichthyidae (Lund & Poplin 1997). The loss of the intertemporal bone and presence of a dermopterotic places *Novogonatodus* at a level above any of the known Devonian actinopterygians according to Gardiner and Schaeffer (1989), but as Coates (1999: 447) noted, this feature has most likely developed independently in a number of higher actinopterygian lineages. We doubt the position of the Middle Devonian stem actinopterygian *Stegotrachelus* suggested by Cloutier & Arratia (2004a) in a highly derived position relative to other basal actinopterygians. Current redescription of this poorly known form by

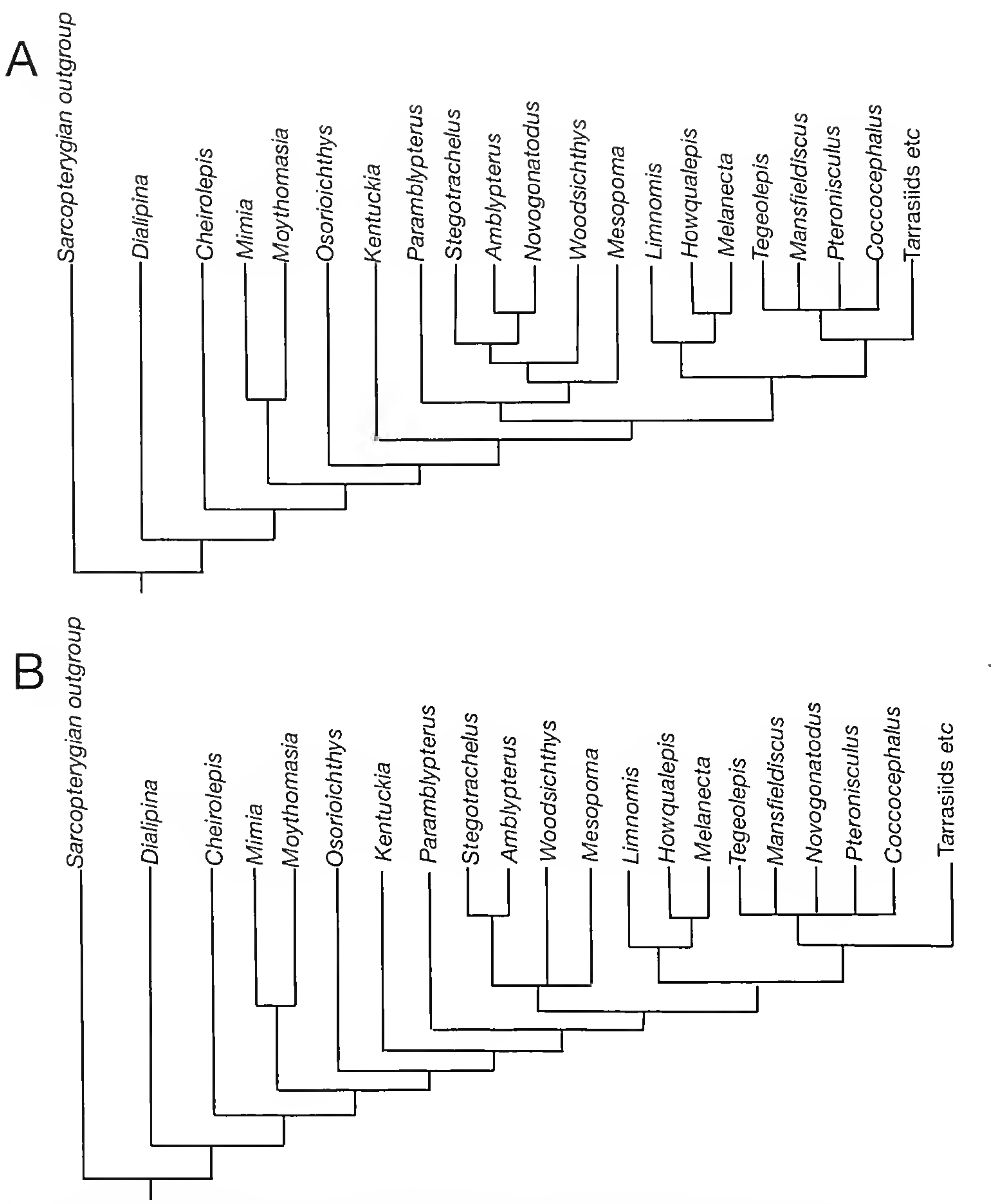

Fig. 5. A, cladogram from Cloutier and Arratia (2004a, fig.13B); B, diagram showing the phylogenic position of *Novogonatodus kasantsevae* suggested by new data presented in this paper, but not run on PAUP.

Brian Schwartz (Cambridge University) should clarify the position of this genus with respect to other basal forms.

The new specimen NMV P216859 adds previously unknown characters of *Novogonatodus kasantsevae* to the data matrix of Cloutier & Arratia (2004a,) shown here in Fig. 5A. These characters may help clarify the relationship between *Novogonatodus kasantsevae* and other actinopterygians. They include (numbered according to their data matrix): 21. Marginal teeth: 0 (vertical) — Coded as 1 in Cloutier & Arratia (2004a); 35. Preparietal area, relative length: 1 (elongated); 36. Snout, shape of: 0 (rounded); 37. Rostral condition: 0 (present as a distinct bone); 39. Median rostral, shape of: 1 (equal width anterior and posterior); 44. Nasal bones: 1

(nasal bone with notches for the anterior and posterior nares); 47. Postorbital bone(s): 1 (absent); 50. Pineal opening: 0 (present); 51. Pineal opening, position of: 1 (parietal region); 52. Pineal plate: 1 (absent); 53. Parietal, number of: 0 (one pair of parietals); 55. Postparietal: 0 without pointed anterolateral process; 56. Postparietal shape: 2 (short and rectangular); 57. Postparietal, relative size of: 2 (postparietal shorter than parietal {parietal up to two times length of postparietals}); 59. Postparietal, contact of: 0 (postparietal contacts extrascapular); 60. Extrascapular, number of: 0 (three extrascapulars); 61. Dermal supraoccipital: 0 (absent); 70. Dermopterotic: 1 (present); 71. Intertemporal: 1 (absent); 76. Spiracle, shape of: 0 (angular shape); 86. Suborbital bone, arrangement of: 1 (many rows); 92. Quadratojugal: 0 (present); 93. Quadratojugal, size of: 0 (small); 100. Angle of preoperculum: 0 (less than 90 degrees); 103. Gap between the opercular series and skull roofing bones: 1 (absent); 110. Operculum, contact with lateral extrascapular: 1 (in contact); 129. Supraorbital canal, trajectory of: 0 (ends in postparietal); 138. Vertical preopercular pit-line: 0 (present); 139. Preopercular canal: 1 (to postorbital corner); 152. Clavicle contact: 1 (short); 154. Body form: 0 (fusiform/elongate) (coded as deep and round in Cloutier and Arratia 2004a). We suggest from this distribution of characters that *Novogonatodus* probably lies somewhere crownward of the *Howqualepis-Melanecta* clade (Fig. 5B), but until the character matrix is run again with new data to clarify some of the many ambiguous codings, the position of *Novogonatodus* will remain unsupported.

Ongoing work on the phylogeny of lower actinopterygians is dependent upon further description and clarification of anatomical features in basal taxa, such as *Stegotrachelus*, *Cheirolepis* and *Dialipina*. Most recent attempts have used numerous braincase and gill-arch characters (Gardiner et al. 2005), features rarely seen in most Middle Palaeozoic actinopterygians. Only one Lower Devonian actinopterygian is known from neurocranial material (Basden et al. 2000; Basden & Young 2001), yet most of the dermal bones of the head are unknown in that species. For these reasons, it is unlikely that basal actinopterygian phylogeny will be stabilised in the near future unless imperfectly known taxa are disgarded from analysis, or simpler character sets reflecting general dermal bone trends are used. Current work at Museum Victoria by Brian Choo redescribing the three-dimensional Gogo Formation actinopterygians (now known to contain three taxa) will greatly contribute towards this aim and may shed future light on the position of the problematic Mansfield forms.

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THE 1744 CERAMIC PATENT OF HEYLYN AND FRYE: 'UNWORKABLE *UNAKER* FORMULA' OR LANDMARK DOCUMENT IN THE HISTORY OF ENGLISH CERAMICS?

William R. H. Ramsay, Frank A. Davenport & Elizabeth G. Ramsay

Ramsay, W. R. H., Davenport F. A. & Ramsay E. G. The 1744 ceramic patent of Heylyn and Frye: 'unworkable *unaker* formula' or landmark document in the history of English ceramics? *Proceedings of the Royal Society of Victoria* 118 (1): 11–34. ISSN 0035-9211.

The evolution of ideas, assumptions, and peer-group constraints regarding the efficacy, or otherwise, of the 1744 ceramic patent of Edward Heylyn and Thomas Frye is discussed. Various concepts, notions, and dictates are investigated and it is observed that because of these our understanding as to the significance and importance of the 1744 patent has been undeservedly diminished over the last 150 years. Circular arguments, misleading transcripts of the patent itself, and unwarranted and unsubstantiated assertions have all combined to lessen the stature of this patent. In contrast, recent research concludes that the 1744 patent is a landmark document, which is anything but unworkable, experimental, uncertain, or hesitant. This patent on the one hand relates the 'A'-marked group of porcelains to the patent itself, and on the other hand to Cherokee clay (*uneka*) located in the southern Appalachians. In addition it offers circumstantial evidence linking these porcelains to the experimental kiln-firings of Andrew Duché in Savannah, Georgia. It is concluded that the 1744 patent is central to any future understanding of this earliest period of porcelain development in the English-speaking world.

Keywords: Edward Heylyn, Thomas Frye, Andrew Duché, 1744 ceramic patent, 'A'-marked porcelain, Bow porcelain, hard-paste porcelain, Chelsea porcelain

OF LATE there has been a number of papers investigating the birth of the English porcelain industry (Ramsay et al. 2001, 2003, 2004 a, b) and one of the significant conclusions drawn from these works is that our understanding of the period relating to the inception of the industry may have been unnecessarily impeded because of various confusions, beliefs, and unsubstantiated assertions, which over time have tended to become articles of faith. One of these beliefs relates to the perception over the last 100 years or more, that the 1744 ceramic patent of Heylyn and Frye was at best experimental and at worst, unworkable. Secondly, since the recognition of the 'A'-marked porcelains as a coherent group in the 1930s there has been a perceived reluctance in relating these porcelains to the 1744 patent and to the patentees, Edward Heylyn and Thomas Frye. The third aspect relates to the assumed pre-eminence of the Chelsea porcelain manufactory.

In the case of Chelsea there has for the last hundred years or so been the relatively unanimous view that it was most likely the first factory to produce commercial porcelains. Nightingale (1881) commences his account of English porcelains by stating that Chelsea was incontestably the most important, both artistically and otherwise, of any of the English manufactories. Adams and Redstone (1981: 19) state that Chelsea probably does bear away the 'palm' for the earliest founded English porcelain manufactory. More recently Sandon (1989) whilst noting that collectors will always argue over which was the first English porcelain factory, concludes that Chelsea is the only one which can begin to lay claim to that title.

We suggest that several factors have coalesced to develop this belief that Chelsea was not only the first manufactory but also the role-model for other concerns such that in some way it may have held a monopoly over other English-made porcelains for a short period (Sandon 1989: 17). Firstly, the Chelsea recumbent goat-and-bee jugs are generally regarded as representing the earliest English porcelain wares, with several examples bearing an incised date on their base of 1745 (Adams 2001; Godden 2004a). This in itself has tended in many instances to impose a chronostratigraphical barrier to any enquiry into porcelain developments that may have occurred prior to 1745. Secondly, the earliest extant dated Bow porcelain wares relate to 1750 (Tait 1959) thus casting uncertainty as to what, if any, Bow wares were produced prior to this date. Consequently, in the belief that there was no rival concern of comparable stature, there has been a preference to assign to Chelsea various references such as the mention in the Vincennes Privilege of 1745 to a new establishment, which had just been formed in England whose porcelain appeared finer than that of Saxony because of

its composition (Hobson 1905; Hurlbutt 1926; Legge 1984; Drageseo 1993).

With regard to the 1744 patent, whilst reference is often made to this document (Her Majesty's Stationery Office, 1856) by various writers (Burton 1902; Dillon 1904; Watney 1963, 1973; Gabszewicz 2000) there have always been doubts and questions raised as to the efficacy and verisimilitude of this patent. Possibly Begg and Taylor (2000: 18) best summarise the currently accepted view of the 1744 patent when they state,

> Porcelain which fits the first patent has not been identified, but contemporary accounts indicate that actual production had commenced by 1747, if not before.

The central thrust of our contribution in this paper is to take the 1744 patent of Heylyn and Frye and to examine the various ideas and notions that have evolved and constructs imposed on this patent over the last 150 years. It is no accident that during this period the 1744 patent has been viewed by many at best hesitantly and at worst in a somewhat dismissive manner and these aspects have contributed to this patent being diminished and its full significance to the nascent English porcelain industry not fully being appreciated or recognised. It is our contention that the 1744 patent is a landmark document in English ceramic history and that this document offers significant insights into the origins of this porcelain industry. By rehabilitating and restoring this patent to its rightful place in English ceramic history, we suggest that a better appreciation of these earliest years in Anglo-American porcelain development may be obtained and it may now be opportune to re-evaluate the role played by the Bow proprietors and their porcelain output during early English porcelain production.

THE ENGLISH PATENT SYSTEM

About 120 years before the enrollment of Heylyn and Frye's 1744 patent, Great Britain, or more correctly England, established the world's first patent system. Prior to 1624 the issuance of letters patent was a royal prerogative. The monarch issued letters patent ostensibly for the technological good of the country, but increasingly during the reign of Elizabeth I and James I, for the good of the Royal exchequer. For example, during the reign of Queen Elizabeth I monopolies were granted for the manufacture and sale of commodities such as soap, salt, glass, iron and paper, to the ever-increasing displeasure of the populace. The sale of monopolies continued under James I, however, this income generating practice ended in 1624 with Parliament passing the Statute of Monopolies.

The Statute rendered all monopolies "*utterly void and of no effect*", however, section 6 of the Statute excepted grants for 14 years or less, according to certain fundamental tenets namely, "*making of any new manufacture within the realm*" by "*the true and first inventor*". These tenets still continue to provide the basis of all patent systems worldwide. Since 1624, apart from the period of the Protectorate, this patent system has continued to operate in Great Britain. Prior to the 1624 Statute of Monopolies, the granted monopolies included few inventions when retrospectively considered against the fundamental tenets of, first and true inventor of an invention new within the realm. In the 1850s Englishman Bennet Woodcroft cataloged and numbered all (14,357) English patents issued between 1617 and 1853. It is as a direct result of Woodcroft's endeavors that copies of these early patents are available for both edification and speculation.

Various ceramic scholars have studied Heylyn and Frye's 1744 patent and have analyzed both the process disclosed and the meaning of the text. Patents are like living documents; the author (inventor) communicated a process or arrangement defining his invention. However, it is inevitable that his words are attributed new interpretations and hidden meanings. Even today the final arbiter of patent word meaning is a trial judge. Thus, to impute meanings to patent wording some 200 years later can be speculative.

Jewitt (1878) details the history of the various ceramic patents taken out in England commencing from the 17th century. On April 23rd, 1672, John Dwight took out a patent stating that,

> … he had discovered the Mistery of Transparent Earthen Ware, comonly knowne by the Names of Porcelaine or China and Persian ware, as alsoe the Misterie of the Stone Ware vulgarly called Cologne Ware.

This patent expired in 1684 and a new one specifying in greater detail the various articles and wares, was granted in June, also for a term of fourteen years. Jewitt comments that by the early 18th century the art of pot-making began to accelerate; for in the period from 1722–1749, a space of twenty seven years, no-less than nine separate patents were taken out commencing with Richard Holt and Samuel London who applied for a patent for,

> … a certain new 'composicon' or mixture (without any sort of clay) for making of white ware, which is formed and moulded in a method hitherto not known or practised, and far surpasses the finest of delf ware, or any other sort made in any part of Europe …

THE 1744 PATENT OF EDWARD HEYLYN AND THOMAS FRYE

The patent document

Watney and Charleston (1966) record that among the State Papers Domestic in the Public Records Office are various petitions for patents and in some instances the original depositions, law officers' opinions, and other relevant papers. In the case of the so-called ' Bow first patent' of Edward Heylyn and Thomas Frye a deposition was sworn at the Public Office on October 8th, 1744 with Heylyn and Frye's original signatures (Public Record Office, S.P. 36/64). On November 21st the Attorney-General reported on the petition and addressed his report to Earl Granville, one of His Majesty's Principal Secretaries of State. On December 6th the patent application was filed, affixed with the Great Seal of Great Britain, and was granted on the proviso that Heylyn and Frye,

> … describe and ascertain the nature of our said Invention, and in what manner and of what materials the same was to be performed, by an instrument in writing, under our hands and seals, or the hand and seal of one of us, …

Their specification was required to be deposited in writing and signed by one or both patentees within four months of December 6th otherwise the patent,

> … should cease and be void.

This specification was subsequently handed in to the Petty Bag Office (one of three depositories) on April 5th, 1745, (with one day to spare) stamped and awarded sealed protection. However the term of protection ran for fourteen years from the grant date of December 6th of the previous year. The Heylyn and Frye patent was reprinted and published at The Great Seal Patent Office in 1856 (Her Majesty's Stationery Office, 1856) and the specification contained in this reprint was proof read against a clerk's long hand copy (C/210/4) of Heylyn and Frye's written filing and now housed in the National Archives, Kew. Apart from punctuation differences, the 1856 reprinted version was found to be an accurate transcription. The following is a copy of the 1856 version of Heylyn and Frye's December 6th 1744 patent:-

> TO ALL TO WHOM THESE PRESENTS SHALL COME, we, Edward Heylyn, in the Parish of Bow, in the County of Middlesex, Merchant, and Thomas Frye, of the Parish of Westham, in the County of Essex, Painter, send greeting.
>
> WHEREAS His most Excellent Majesty King George the Second, by His Royal Letters Patent, under the Great Seal of Great Britain, bearing date at Westminster, the Sixth day of December, in the eighteenth year of His reign, reciting that whereas we, the said Edward Heylyn and Thomas Frye, had, by our Petition, humbly represented unto His said Majesty that we had, at a considerable expence of time and money in trying experiments, applyed ourselves to find out a method for the improvement of the English earthenware, and had at last invented and brought to perfection "A NEW METHOD OF MANUFACTURING A CERTAIN MATERIAL, WHEREBY A WARE MIGHT BE MADE OF THE SAME NATURE OR KIND, AND EQUAL TO, IF NOT EXCEEDING IN GOODNESS AND BEAUTY, CHINA OR PORCELAIN WARE IMPORTED FROM ABROAD;" which Invention we, the Petitioners, apprehended would be of vast advantage to the kingdom, as it would not only save large sums of money that were yearly paid to the Chinese and Saxons, but also imploy large numbers of men, women, and children; and that as many and as great benefits would arise therefrom to this nation, as from the woolen or iron manufactories, in proportion to the numbers of people that would be employed therein, His Majesty did therefore, of his especial grace, certain knowledge, and meer motion, give and grant unto us, the said Edward Heylyn and Thomas Frye, our extors, admors, & assigns, His especial licence, full power, sole priviledge & authority, to make, use, exercise, and vend our said Invention in that part of Great Britain called England, Dominion of Wales, and Town of Berwick-upon-Tweed, to hold to us, the said Edward Heylyn and Thomas Frye, our extors, admors, and assigns, for the term of fourteen years from the date of the said recited Letters Patent. In which said Letters Patent there is contained a provisoe, that if we, the said Edward Heylyn and Thomas Frye, should not particularly describe and ascertain the nature of our said

Invention, and in what manner and of what materials the same was to be performed, by an instrument in writing, under our hands and seals, or the hand and seal of one of us, and cause the same to be inrolled in His Majesty's High Court of Chancery, within four calendar months after the date of the said recited Letters Patent; that then the said Letters Patent, and the libertys and advantages thereby granted, should cease and be void, as in and by the same Letters Patent (relation being thereunto had) may more at large appear.

NOW KNOW YE, that we, the said Edward Heylyn and Thomas Frye, in pursuance of the said provisoe, contained in the said recited Letters Patent, do hereby describe and ascertain the nature of our said Invention, and the manner and of what material the same is to be performed, as herein-after is mentioned (that is to say):-

The material is an earth, the produce of the Chirokee nation in America, called by the natives unaker, the propertys of which are as follows, videlicet, to be very fixed, strongly resisting fire and menstrua (dissolution), is extreamly white, tenacious, and glittering with mica. The manner of manufacturing the said material is as follows:- Take unaker, and by washing seperate the sand and mica from it, which is of no use; take pott ash, fern ash, pearl ash, kelp, or any other vegetable lixiviall salt, one part of sands, flints, pebbles, or any other stones of the vitryfying kind; one other part of these two principles form a glass in the usual manner of making glass, which when formed reduce to an impalpable powder. Then mix to one part of this powder two parts of the washed unaker, let them be well worked together until intimately mixed for one sort of ware; but you may vary the proportions of the unaker and the glass; videlicet, for some parts of porcelain you may use one half unaker and the other half glass, and so in different proportions, till you come to four unaker and one glass; after which knead it well together, and throw it on the wheel, cast it into moulds, or imprint it into utensills, ornaments, &c.; those vessells, ornaments, &c., that are thrown, should be afterwards turned on a lathe and burnished, it will then be in a situation to be put into the kiln and burned with wood, care being taken not to discolour the ware, otherwise the process will be much hurt. The first burning is called biscuiting, which if it comes out very white, is ready to be painted blue, with lapis lazuli, lapis armenis, or zapher, which must be highly calcined and ground very fine. It is then to be dipt into the following glaze:- Take unaker forty pounds, of the above glass ten pounds, mix and calcine them in a reverberatory; then reduce, and to each pound when reduced add two pounds of the above glass, which must be ground fine in water, and left of a proper thickness for the ware to take up a sufficient quantity. When the vessells, ornaments, &c, are dry, put them into the kiln in cases, burn them with a clean wood fire, and when the glaze runs true lett out the fire, and it is done, but must not be taken out of the kiln till it is thorough cold.

In witness whereof, we, the said Edward Heylyn and Thomas Frye, have hereunto sett our hands and seals, this Fifth day of April, in the year of our Lord One thousand seven hundred and forty-five.

Signed EDW^D (L.S.) HEYLYN
THO^S (L.S.) FRYE

Sealed and delivered (being first duly stampt), in the presence of

THO. SHERMAN.
DAN. FENDEN.
CHA^S HEYLYN.

AND BE IT REMEMBRED, that on the said Fifth day of April, in the year of our Lord One thousand seven hundred and forty-five above said, the aforesaid Edward Heylyn and Thomas Frye came before our said Lord the King in His Chancery, and acknowledged the above Instrument, and all and every thing therein contained and specified, in form above written. And also the Instrument aforesaid was stampt according to the tenor of the Statute made in the sixth year of the reign of the late King & Queen William and Mary of England, & so forth.

Inrolled the aforesaid Fifth day of April, in the year above said.

Although commonly referred to as the ' Bow first patent' the authors note the caution by Mr John Mallet who observes that this term may be inappropriate (Ramsay et al. 2001: 492). In the absence of dated Bow wares predating 1750, the earliest extant record which mentions Bow is the published advertisement in the 'Daily Advertiser' on 26th August, 1748 — '*BOW CHINA. GREAT variety of useful and ornamental CHINA to be sold at Mr Mitchells' Toyshop, at the Dial and King's Arms in Cornhill, near the Royal Exchange*'. In addition there is the

reference for a large manufactory lately set up in the village of Bow, in the 4th Edition of Daniel Defoe's *Tour of Great Britain*, which is regarded to have been published in June 1748 (Tait 1963) or July 1748 (Tait 1965). Lastly there is the undated letter written by John Campbell assumed to have been written to Arthur Dobbs of Carrickfergus, in which Campbell mentions his visit to the Bow ceramic concern, the presence of white clay (which could possibly be regarded as a synonym for Cherokee clay), and his less than favourable impression of the concern — thus suggesting a very early date for Campbell's on-site inspection (Daniels, pers. com. 2002). Watney (1963, 1973) dates the letter as 'about June 24th, 1749', but provides no justification and states incorrectly that the identity of the author of the letter was John Campbell L.L.D., a prolific writer and authority on industry and trade, who was made agent for Georgia in 1765. For a correct identification of John Campbell refer to Hood (1968). The letter may have been written on or around May 18th, 1749 based on an inferred companion letter to Earl Granville. Another distinct possibility is that the letter was written around May 1745 (unpublished data) and could refer to any one of a number of Campbell's visits to London, which stretch back to the 1730s. Research into which of these visits to London was the one that Campbell toured the Bow concern is nearing completion. With the foregoing, we accept the terminology 'Bow first patent,' on the basis that the 1744 patent describes the manufacture of porcelain presumably in the vicinity of Bow. In addition both patentees are recognized proprietors of the Bow manufactory during its production of phosphatic wares based on the 'Bow second patent.' In this account we regard as synonymous the terms 1744 patent, Heylyn and Frye patent, and the 'Bow first patent.'

With regard to the above patent we note the following points,

- The patent was signed by five people, the two patentees and two of the others directly related to Edward Heylyn (Charles Heylyn, his son, and Thomas Sherman an uncle). Both Edward Heylyn and Thomas Frye subsequently went on to develop and promote a highly successful ceramic concern using bone ash (Bow second patent of 1749) and because of this record we suggest that the patent is likely to be genuine and was not entered with any intent to defraud or to dissemble the truth.
- Secondly we note that Heylyn gives his address as Parish of Bow and Frye as Parish of West Ham. Thus we suggest that any concern or enterprise that was erected to carry out the manufacture of the associated porcelains would most likely have been in the vicinity of their East London addresses, probably in the general area of the village of Bow.
- Thirdly we draw attention to the clarity of the descriptions as to how these porcelain wares are made and the specifications required for this purpose.
- Lastly in regard to deductions and inferences relating to the kiln-firing of analogue 1744 patent wares, we refer to the publication by Ramsay et al. (2004a).

Other contemporary documents

A second contemporary, primary-source document, in addition to the 1744 patent, is the William Cookworthy letter to his friend, Dr Richard Hingston, dated July 27th, 1745 (Daniels, pers. com. 2002) and not May 1745 (Watney 1963, 1973). In this correspondence Cookworthy describes having met the person who had discovered 'china earth' on the back of Virginia where this person was in quest of mines. Cookworthy discusses the examples of china ware "...*of their making*", which he regards as being equal to the Asiatic and then mentions that this person had gone for a cargo of this special clay, which was essential for the success of the manufacture of this china.

A third contemporary, primary-source document is by Dossie (1758) in *The Handmaid of the Arts*. In this publication, Dossie notes that kaolin is one of the key ingredients of Oriental porcelain and this clay had been discovered in abundance on the back of the Carolinas. He also records that the proprietors of a works near London sent an agent to procure some of this China clay for them.

A further document is the Vincennes Privilege awarded to Charles Adams on July 24th, 1745 by Louis XV. This document states that in England there is one manufacturer of porcelain whose style or appearance is more beautiful than that of Saxony (Meissen) because of its composition. Whilst widely regarded as referring to Chelsea (Drageseo 1993); Tiffen (1874), Chaffers (1863), and Daniels (2003) regard the reference as referring to Bow and in the case of Daniels, as referring specifically to 'A'-marked porcelain, an observation supported through kiln-firing of analogue 1744 patent wares by Ramsay

et al. (2004a). Ramsay and Ramsay (2005b) further support Daniels and list features, compositional, technical, and decorative, as to why the Privilege refers to 'A'-marked porcelain and not to Chelsea.

From the patent and these contemporary documents we note the following, on the reasonable assumption that all four refer to the same ceramic concern and to 'A'-marked porcelain. Two of the documents specifically refer to a China clay, whilst from the patent itself, it can be inferred that the earth or clay described was a primary residual clay, such as a China clay (Binns 1898; Dillon 1904; Hurlbutt 1926). Subsequent research (Ramsay et al. 2001) has shown this clay to belong to the kaolinite group and to comprise some 90% halloysite and 10% kaolinite. Secondly from the patent it can also be inferred that the location of the manufactory was likely to be in East London, possibly in the vicinity of the village of Bow, based on the stated domicile of Heylyn and Frye. Likewise Dossie states that the concern was near London, not near Edinburgh (Charleston and Mallet 1971; Valpy 1987; Mallet 1994,), Stourbridge (Mallet 1994; Young 1999), or Newcastle-Under-Lyme (Freestone 1996). In the case of the Cookworthy letter, it refers to the porcelain carried by the discoverer of the China earth, as being "*of their making*" and from this it has been inferred that the concern was London-based, possibly Bow (Watney 1963, 1973). Three of the documents are very clear that the source of the clay was to be found in the New World on the back of Virginia (Cookworthy), on the back of the Carolinas (Dossie), and in Cherokee territory (1744 patent). This minor discrepancy in location of the clay or earth is discussed by Gilmer (1948) where she notes that at that time the border between the Carolinas and Virginia was poorly known in the '*back country*'. Finally two of the documents specify that an agent was, or had been sent to procure supplies of this clay.

Based on the patent document, Cookworthy's letter, the Vincennes Privilege, and even from the use of China clay, as specified by Dossie, it is possible to deduce that the resultant wares may have been a high-firing, hard-paste porcelain, as subsequently demonstrated by Ramsay et al. (2004a) for analogue 1744 patent porcelain.

In summary we submit that there was a ceramic concern near London producing high-firing, hard-paste porcelain by 1743, which utilised a refractory China clay imported from the New World — from the western Carolinas. William Cookworthy has provided us with an unequivocal and impartial eye witness account of this porcelain, which he described as, "*....equal to the Asiatic*" and composed of China earth derived from the back of Virginia. Likewise the Vincennes Privilege compares porcelain made in England by mid 1745 as compositionally comparable to that of Meissen. There is no known English porcelain of this period, other than 'A'-marked porcelain, which fits such descriptions. Freestone (1996) regards these wares shown Cookworthy as technically consistent with the 'A'-marked porcelain group, whilst Ramsay et al. (2001) regard such wares as in fact belonging to the 'A'-marked group. Ramsay et al. (2004a) have suggested that Cookworthy, who had devoted his life to the discovery of the method of firing hard-paste porcelains in the manner of the Chinese, represented an impartial observer and would not have been unduly impressed had such wares shown him been of a soft-paste composition after the manner of the French; what Solon (1903) refers to as that porcelain vulgarized by the French. We suggest that the inferred 'A'-marked porcelain shown him required the use of a refractory China clay (with a non-lead, high firing Si-Al-Ca glaze), was compact, hard, translucent, with a conchoidal or modified conchoidal fracture, and appeared to be of a hard-paste composition, which was resistant to thermal stress, as was found in both Chinese and Meissen wares.

Response to the 1744 patent by ceramic historians, 1837–2004

As noted in the introduction, the major aim of this contribution is to trace the various ideas and notions that have grown up around the 1744 ceramic patent of Heylyn and Frye and hence arrive at an understanding as to why this patent has received so many negative and dismissive comments during the last 100 years. This investigation commences with Simeon Shaw where he records (Shaw 1837: 436),

> The potters of Bow and Chelsea, from compounding well-washed sand from Alum Bay, Isle of Wight, ground cullet, and pipe-clay, fabricated porcelain, which was covered with a glaze, chiefly of lead, which had considerable demand in the early part of the last century.

No basis or reference for this recipe is provided and it is uncertain as to which Bow wares Shaw was referring to — first or second patent. Moreover there is a subsequent reference to this recipe by Burton (1906), which fails to afford prior acknowledgement

to Shaw. We record that neither the first nor second Bow patents specifies such a recipe, however this composition could conceivably correspond to the early Chelsea triangle period recipe, where the glass cullet employed apparently comprised both a lime-alkali glass and a flint glass — the latter to supply the lead component in the analysis (Tite and Bimson 1991: analysis No. 32699).

De La Beche and Reeks comment in their publication, *British pottery and Porcelain from the Occupation of Britain by the Romans to the Present Time,* published in 1855 that,

> The exact date of the first English porcelain manufactures at Bow and Chelsea does not appear to be correctly known.........The sand used to render the clays perfectly 'dry,' is mentioned as having been obtained from Alum Bay, in the Isle of Wight, a sand which has been extensively employed in the manufacture of glass.

1863 saw the appearance of the first edition of the seminal work by William Chaffers, *Marks and Monograms on European and Oriental Pottery and Porcelain.* In this account Chaffers speculates that someone from America, as recorded by William Cookworthy, probably made terms with the Bow China factory to supply a new earth suitable for making china like the oriental. Chaffers then goes on to provide what might appear to be a transcript of the 1744 patent, but in a manner which greatly abbreviates it, such that the Chaffers' version differs considerably from the patent itself. In particular, the detailed specifications relating to the amounts of clay and glass to be used for the body and glaze are excised. This abridged version of the 1744 patent, notwithstanding Jewitt's expressed concern quoted below, has been reprinted on many occasions in numerous editions of Chaffers' *Marks and Monograms*, with the 15th edition appearing in 1965. Consequently fiction and fact may have commenced to merge resulting in what might appear to be erroneous assertions being made about the patent by various subsequent authors. The Chaffers' misleading version of the 1744 patent is reproduced yet once more below so that it can be compared with the original version of the patent given above,

> Edward Heylin (*sic*), in the parish of Bow, in the county of Middlesex, merchant, and Thomas Frye, of the parish of West Ham, in the county of Essex, painter, took out a patent on the 6th of December 1744 for "a new method of manufacturing a certain mineral (*sic*), whereby a ware might be made of the same nature or kind, and equal to, if not exceeding in goodness and beauty, china or porcelain ware imported from abroad. 'The material is an earth, the produce of the Cherokee nation in America, called by the natives UNAKER.' A glass is formed in the usual way with one part of either 'pot-ash, fern-ash, pearl-ash, kelp, or any other vegetable lixiviall salt,' and 'one part of sand, flints, pebbles, or any other stones of the vitrifying kind,' and reduced to an impalpable powder, and mixed in different proportions, according to the nature of the ware to be made, with 'unaker', from which sand and mica have been removed by washing. They are then kneaded together, thrown or moulded, and put into a 'kiln burned with wood,' called 'biscuiting,' then painted and glazed with 'unaker' and the glass above described; 'they are not to be taken out of the kiln till it is thorough cold.'

In 1878 Lewellyn Jewitt published his two volume set *The Ceramic Art of Great Britain from Pre-Historic Times Down to the Present Day.* Jewitt's main contribution with regard to the 1744 patent was to reproduce the wording of the patent (page 112) in an accurate manner using the original spelling but leaving off the names of the two patentees and the three witnesses at the conclusion. Jewitt further notes that nothing definitely is known as to the date of the first establishment of this important china manufactory located at Stratford-le-Bow, however he deduces that the concern must have been in existence some time prior to 1744, because it was in that year that the patent was taken out. He then admonishes Chaffers and states,

> This specification I have printed in full on page 112, and it will be found of the highest interest and totally different from that what is put forth by Chaffers as a copy of it.

Here arises what we regard to be the first major confusion regarding the 1744 patent, in that Chaffers' imprecise version of the patent has been reproduced endlessly, whilst Jewitt's excellent transcription has not. Reliance on the Chaffers' version has resulted in what might appear to be erroneous assertions being made about the patent by various subsequent authors, with a possible example being Bradshaw (1992).

A. H. Church, a well-regarded chemist with both an MSc and a DSc, was Professor in Chemistry at the Royal Academy of Arts, London, and a member of the Royal Society. He was most likely the first to undertake chemical analyses on wasters

of Bow porcelain, which had recently been recovered from the Messrs Black and Sons' site located on the southern side of Stratford High Street There is some uncertainty as to the identity of the manufactory whose phosphatic wares were analysed by a Mr. Cooper and reported on by de la Beche and Reeks (1855). Church, in his Cantor Lecture of December 13th, 1880, advised that the 1744 patent's specifications require one part of potash, one of sand or flint and *unaker*. In 1885 Church published his book *English Porcelain* and this publication repeated the 1880 lecture and required the glass frit specified in the patent to comprise one part potash (potassium carbonate, K_2CO_3) and one part sand or flint (silica, SiO_2).

> The two patents taken out in connection with the Bow works disclose two essentially different porcelain-bodies. The 1744 specification of Edward Heylyn and Thomas Frye gives, as the ingredients, one part of potash, one part of sand or flint, and from one to four parts of a kind of porcelain-clay called unaker, from which the sand and mica had been removed by washing, from the Cherokee territory, North America: the glaze contained seven of potash-glass to one of unaker.

We consider this interpretation by Church of the composition of the glass frit used for both the body and glaze in the 1744 patent to be incorrect and unfortunately this incorrect composition has led to a second train of invalid assumptions and assertions, which can be traced from this date of 1885 through to Watney (1963, 1973) and beyond. The 1744 patent states as follows,

> … take pott ash, fern ash, pearl ash, kelp, or any other vegetable lixiviall salt, one part of sands, flints, pebbles, or any other stones of the vitryfying kind; one other part of these two principles form a glass in the usual manner of making glass, which when formed reduce to an impalpable powder.

Based on the 1744 recipe, we deduce the following components would or could have been included in the glass frit used by Heylyn and Frye (Table 1).

From Table 1 it can be seen that based on the patent wording alone, the glass frit, by virtue of the vegetable ashes specified, would have contained CaO, MgO, and even small amounts of P_2O_5, in addition to SiO_2 and K_2O. The practice of burning a calcium source (limestone) with fern, such as bracken, after the manner of the Chinese would have

	1	2	3	4	5
SiO_2		40.4	6.4	14.3	20.78
Al_2O_3		12.0	2.3	10.3	4.13
FeO		0.7	0.6	2.7	1.35#
MgO		11.0	1.4	6.1	2.98
CaO		20.6	49.8	37.6	34.12
Na_2O		0.2	0.1	bdl	0.32
K_2O	68.2	2.4	0.2	2.6	3.93
P_2O_5		4.4		4.7	1.94
LOI	31.8	8.3	38.1	21.5	29.93

1. Pearl ash (potassium carbonate)
2. Bracken ash fully washed (Leach 1940)
3. Bracken ash burnt with lime (McMeekin 1967)
4. Box ash fully washed (Leach 1940)
5. Wood ash from Shenhou (Yanyi 1987)

bdl. Below detection level
\# Total iron as Fe_2O_3

Table 1. Chemical compositions (wt%) of various mineral substances and possible vegetable ashes used for glass making as suggested in the 1744 patent

been common knowledge by then in England after Père D'Entrecolles, a Jesuit missionary to Jingdezhen (Ching-tê-Chên), wrote his letters in 1712 and 1722 on Chinese ceramic practices. These in turn were published in Paris in 1717 and 1722 and then incorporated in Jean-Baptiste Du Halde's *Description géographique … de l'empire de la Chine* of 1736, with the English edition appearing in 1738–41. As noted by Ramsay et al. (2004a) the likely source of sodium is possibly a problem although the use of kelp could produce minor levels of this element. They also note that there is some suggestion in the patent that the patentees may have had some working knowledge of soap manufacture and an understanding of methodologies by which high concentrations of sodium may be obtained because of the use of the words *lixiviall salt* ('lye' when in solution). Simeon Shaw (1837) records that sodium carbonate was obtained from lixiviating the ashes of incinerated marine vegetables or those located on the sea-shore (eg. *Salicornia Europæa).* Likewise he notes that the sodium carbonate is derived from a plant grown in Spain and the Levant under the Spanish name *Barilla*, whilst kelp supplied from the Orkneys, in quantities greater that

3,000 tons annually, produced but some 3 wt% alkali. More recently a greater proportion of the carbonate was manufactured from common salt.

Both sodium and potassium are alkali metals, whose oxides act as fluxes on silica in broadly the same manner. Cristobalite, the high temperature form of silica, melts at 1,710°C to a glass, which can be cooled without further crystallizing. However the addition of 25% Na_2O will lower the melting point from 1,710°C to 793°C, a reduction of more than 900° (Phillips 1941). This sodium silicate is readily soluble in water and forms a viscous, alkaline solution known as water glass because the presence of modifiers such as Na_2O alter the structure by cleaving the Si-O-Si bonds to form Si-O.Na linkages. Howe-Grant (1994) records that such glasses, known as 'invert glasses' can be made with the oxides of the alkali metals Li_2O, K_2O, and Na_2O and where these alkali silicates have a silica : alkali (mol prop) ratio ranging from 0.5–3.4 they are the basis of the soluble silicate glass industry. Smaller cations having a higher charge density (e.g. Li^+) produce less soluble silicate glasses with $Li^+ < Na^+ < K^+$ (Howe-Grant 1997). Phillips notes that to overcome the water solubility of the alkali silicates, other materials can be added — one such being lime. In the case of water glass, addition of lime further reduces the melting point till the triple eutectic is reached (21.3 wt% Na_2O, 5.2 wt% CaO, 73.5 wt% SiO_2) at 725°C (Phillips 1941). It is the addition of multivalent metal ions such as Al^{3+} or Ca^{2+} that significantly reduce glass solubility and mixtures of alkali and alkaline earths give glasses higher durability and significantly reduced glass solubility than straight alkali silicates. Shaw (1837: 494) records,

> The essential components of Glass are 'sand' and 'alkali', with the addition of 'lime, nitre, borax', and 'oxides of lead, arsenic', and 'manganese,' in some of the kinds.

We believe that Church's assertion that potash was the only flux employed is in error and is not in accord with the wording in the patent itself. Both CaO and MgO would have been required additives by nature of their common presence in various fern and vegetable matter. We do however accept the collective observation made by various authors (Church 1885; Hurlbutt 1926) that the resultant glass was a lead-free glass. These points need to be borne in mind when discussing the assumptions and experiments subsequently undertaken by Burton in 1902 on the patent. We suggest that the absence from the patent specification by Heylyn and Frye of a distinct calcium source was not obfuscation; but was merely an error of omission since, at that time, it was common knowledge to those of '*ordinary skill*' in the art of glass making, that calcium {or possibly magnesium (Ramsay and Ramsay 2005a)} was required to stabilize a lead-free, alkali glass (Ramsay et al. 2004a).

Bemrose (1898: 4) in discussing the Bow factory quotes from the introductory remarks made by Professor A. H. Church in the Lady Charlotte Schreiber catalogue and hence would appear to accept Church's assertion that the recipe for the 1744 patent comprised (quartz) sand, potash, and a kind of porcelain clay.

> The porcelain made at Bow was of two kinds. The earlier body contained a kind of porcelain clay associated with sand and potash; in the later composition bone-ash and pipe clay were substituted for the porcelain clay, while a lead glaze was used.

In 1902 W. Burton published his highly influential *A History and Description of English Porcelain* At the time Burton was Director of Pilkington's Tile and Pottery Co., and prior to that he was chemist to Josiah Wedgwood and Sons, so he had a wealth of experience on which to draw yet, as with Bemrose, he appears to have accepted and closely followed Church's formula for the manufacture of the glass frit although if so, no prior acknowledgement to Church is given. This account by Burton (1902: 10) is so central to the attitude adopted towards the 1744 patent in subsequent years that we quote Burton at some length,

> It may be suggested that this origin would be found in the Heylin (*sic*) and Frye's patent of 1744 already alluded to, but that patent is not worth the paper on which it was written.* The particulars given are purposely vague, but the glass or frit is a pure alkaline glass, which when ground in water produces a soluble glass. This, when mixed with china clay, instead of producing a plastic working mass, sets almost like cement, and could never have been fashioned into shape by any ordinary pottery method, and the description of the mixtures suggests that the patentees were anxious to protect the use of substances of which they had no practical experience. Compare, for instance, the mixtures proposed by Heylin and Frye's patent of 1744–1745 with the mixtures actually used at Sèvres:-

HEYLIN AND FRYE'S PATENT.	*SÉVRES.#*
Frit.	*Frit.*
50 parts Potash	*Sand 60 parts*
50 parts Sand	*Nitre 22 parts*
fused together	*Salt 7.2 parts* } *fused together*
	Soda 3.6 parts
Body	*Alum 3.6 parts*
	Gypsum 3.6 parts
50 parts of the above glassy frit	*Body*
50 parts of Unaker (china clay),	*75 parts of the above glassy frit*
varied to	*17 parts of chalk*
20 parts frit	*8 parts of calcareous clay.*
80 parts Unaker	

Not only were the proportions of Heylin and Frye entirely wrong, but their frit was useless for its supposed purpose.

* Exhaustive experiments have convinced the author that no porcelain could have been made of the materials and in the manner specified in this patent.

Brongniart, 'Traité des Arts Céramiques ,' Vol. II., p. 460. Edition 1877.

From the above quote it appears that Burton was strongly influenced by Church in his choice of a glass frit composition comprising one part of silica sand to one part potash. It is not apparent why Burton followed this glass frit composition, which is neither in accord with the patent specifications regarding the starting materials, nor in accord with common sense glass-making techniques as again specified in the patent, "*Form a glass in the usual manner of making glass, ...*". Likewise we are uncertain as to the basis for the ratio of one part silica to one part potash. We cannot accept the claim by Burton that the particulars contained in the patent are purposely vague, a claim that reverberates through subsequent writings during the 20th century. We regard the patent specifications, with the possible exception of the manner of making a glass in the usual manner, to be both reasonably clear and precise. We accept, without experimental replication, the results reported by Burton that this silica-potash glass initially dissolved when ground under water and then when mixed with kaolin clay the mixture set almost like cement. On this basis we can understand why Burton declared that the patent was not worth the paper on which it was written and we can suspect why, some sixty years later, Watney (1963, 1973) states that the recipe to be almost certainly unworkable. Yet strangely by page 59 Burton in the same volume has a minor change of heart and states,

> There is no information how these two men, one of whom is described as a merchant and the other as a painter, came to know of the existence of china clay (the 'unaker' of the patent). Neither has it occurred to anyone to enquire whether it would be possible to make a porcelain in the manner and of the materials specified. Possibly the description given is purposely vague, but there can be no doubt that porcelain was never made in any quantity under the patent.

Here we see Burton stating on the one hand that the patent was not worth the paper it was written on and emphatically stating that no porcelain could have been made of the materials and in the manner specified in this patent, yet on the other hand in the same publication, suggesting that there was a possibility that some porcelain may have been made according to the 1744 patent — although not in any quantity. This somewhat ambiguous and apparently contradictory view of the patent reappears with Tait (1963) some 60 years later.

A Brief History of Old English Porcelain and its Manufactory was published by M. L. Solon in 1903 and in this publication he mentions curious clays and stones which had been brought over by a traveller from America, who offered to sell these new discoveries to the Bow manufactory where china ovens were already at work. Interestingly Solon declares that the experimental results proved satisfactory with a result that Heylyn and Frye entered into partnership, bought a large consignment of the American clays, and took out a patent by which they secured the sole rights to this material in the manufacture of porcelain. While Solon suggests that the ceramic works must have been in full working order for a few years prior to late 1744, his final conclusion on page 33 is,

> So little promising was the use of Unaker that its mention disappeared completely in the specification of the second patent taken by T. Frye in 1748, and pipe-clay took again the place it occupied in the composition of the body before the advent of the foreign intruder.

Dillon (1904: 342) states that Heylyn and Frye professed to make porcelain by mixing a potash-

silica glass with *uneka*[1] clay, no doubt a kind of kaolin and whose use preceded by some years that of the Cornish china clay. He concedes that possibly something like porcelain was made at Bow for a short time using these incongruous materials. Here Dillon writes as accepted fact that the glass frit used was of a potash-silica composition further illustrating the influence of Church (1885) and Burton (1902).

Church (1911) on publishing through the Victoria and Albert Museum writes,

> The 1744 specification of Edward Heylyn and Thomas Frye gives, as the ingredients, one part of potash, one part of sand or flint, and from one to four parts of a kind of porcelain-clay called 'unaker,' from which the sand and mica had been removed by washing, from the Cherokee territory, North America: the glaze contained seven of potash-glass to one of 'unaker.' This specification describes, incorrectly enough as to the proportions of the materials employed for the body, how to make a glassy porcelain.

Again Church persists with the employment of a potash glass and he makes no mention of Burton's experimental results, where the mixture is described as setting like cement. Burton then subsequently published two further books, the first being *Porcelain its Nature Art and Manufacture* in 1906 and the second *A General History of Porcelain* in two volumes, published in 1921. Unfortunately these contributions, with respect to the 1744 patent and the overall Bow porcelain output, cloud the issue even further. Burton (1906: 233) notes that although some writers have given a starting date for Bow as early as 1731, most modern authorities agree that the first reliable information on the concern commences with the patent of December 6th, 1744, for the production of porcelain from an earthy mixture produced by the Cherokee nation in America and a frit formed by melting together sand and potash. He then continues,

> I have already pointed out, in my history of English porcelain, that no ware could have been made of the materials and the method specified in the patent, and though other writers have remarked that the specification was purposely vague, even to the point of being misleading, I am still of the opinion that when Helyn (sic) and Frye applied for the patent in 1744 they were really trying to protect a partially-learnt secret process; and the origin of the Bow porcelain, as of the other early English porcelains, is to be sought in the information communicated by wandering experts or experimentalists from one of the French factories.

From the above comments it can be seen that Burton accepts that the earthy mix used originated from the Americas, that no such porcelain could have been made according to the 1744 recipe, that Heylyn and Frye were being purposely vague, almost to the point of being misleading, and that the early English porcelain factories were indebted to information derived from France.

However on page 235 Burton (1906) appears to 'invent' a new porcelain body, which he confers on a small group of early Bow wares, assumed by him to pre-date the onset of the phosphatic second patent wares of Thomas Frye.

> We find among the authentic Bow pieces markedly different types of body and glaze. Certain little ink-stands, which bear the legend Made at New Canton, 1750 enable us to fix with certainty the appearance of the earliest wares. These are nearly always thick in substance, and not very skillfully fashioned......Where this early ware is thick it is quite opaque, but in thin parts it is translucent and has a beautiful, warm, creamy tone. The glaze on such pieces is sometimes gathered up in drops or patches, when it always has a distinct yellow tint, due to the high proportion of lead, and for some reason it has often become iridescent from surface decomposition. This is the ware which in all probability was introduced from France; but after a few years we find an entirely different ware being used, which is much whiter in tone, and this ware undoubtedly contained bone-ash, probably added to make the earlier porcelain mixture more stable in firing.

On page 227 Burton (1906) expands on the recipe for his 'invented' Bow composition.

> The earliest bodies, such as those of Bow and Chelsea, were of the French glassy type, the bodies being made from pipe-clay, sand from Alum Bay, and glass; while the glaze was simply a fusible English flint-glass, rich in lead. In our account of French porcelain we have pointed out that such mixtures were exceedingly difficult of fabrication, and as early as 1750 calcined bones were added to the other ingredients of the body, as it was found that this gave more manageable mixtures, besides making the ware whiter.

1 The anglicised spelling of this Cherokee word for white is *unaker*. Where not used in a quotation we have used the Cherokee spelling *uneka*.

This idea of a second type of clay (pipe-clay) harks back to his 1902 publication where on page 60 Burton states,

> Nothing is known of any factory belonging to Heylin and Frye, and it can only be surmised that they may have spent some years in trying to make porcelain after the manner set forth in this patent, and with the substitution of some other form of clay for the 'unaker.' If such were the case, they must soon have found that the potash glass described in their patent was also useless for such a purpose, and they would be plunged into a sea of experiments.

The 1906 recipe of pipe-clay, sand from Alum Bay, Isle of Wight, and glass cullet with an associated lead-based glaze, appears to have been taken from Shaw (1837). In his 1921 publication Burton complicates the situation even further on page 47 where he might appear to be suggesting that some wares were made according to the 1744 patent, but with a lead glaze.

> The first Bow factory, like so many early Continental factories, is said to have been started in a glasshouse, and the partners must have embarked on a sea of troubles in attempting to make a porcelain from potash-glass and Cherokee clay, for such a mixture would not be very tractable, especially in unskilled hands, and the examples of this earliest Bow porcelain are rather thick in substance, not very white or translucent, and are covered with a soft rich glaze of a decidedly yellow tint, which evidently resembled the contemporary earthenware glazes in containing a large percentage of lead oxide. Indisputable examples of this class of Bow porcelain are found in the round inkstands, with a branch of flowering prunus painted in bright enamel-colours, which bear round the top a painted inscription 'Made at New Canton, 1750'. Other specimens are similarly marked with the date 1751, and the sale lists prove that they were made to 1757 at least.

From this collection of somewhat confusing, and at times possibly contradictory ideas, we conclude that Burton accepted Church's assertion that the glass frit employed comprised crushed silica and potash alone. Secondly we note that Burton appears to require the pre-second patent wares to comprise a pipe-clay (together with sand from Alum Bay and glass) in some instances and Cherokee clay and potash glass in other instances. We also note Burton's continued attempt to employ the use of a lead glaze on these early wares. We speculate as to whether or not Burton may have been influenced by Chaffer's significantly abbreviated version of the 1744 patent in which most of the specifications relating to body and the glaze were either deleted or significantly abbreviated. This might explain Burton's claim in 1902 that the particulars given are purposely vague and might help to explain why he resorted to Simeon Shaw's recipe of a pipe-clay body and lead-rich glaze composition for the pre-second patent Bow wares. One clue to the possibility that he may have been reliant in part on the Chaffers' transcription of the 1744 patent is Burton's quote in his 1921 publication where he records the patent as follows,

> an earth the produce of the Cherokee nation in America, called by the natives 'unaker,'

Here Burton follows the incorrect Chaffers' version where the spelling of *Cherokee* is used and not *Chirokee* as found in the patent or in the correct transcript supplied by Jewitt. Regardless of whether Burton was influenced by the Chaffers' version of the patent or not, we have by the early 1920s a collection of conflicting ideas, some proposing compositions, both body and glaze, without any apparent basis in the patent itself, others claiming that the patent particulars were purposely vague or not worth the paper on which they were written, and that the partners must have embarked on a sea of troubles in using a mixture of Cherokee clay and potash-glass, and yet others suggesting that the use of *uneka* lacked but little promise. Collectively these views and statements have acted as a negative platform on which more recent attitudes relating to the patent can be seen to have been based. Once this thinking became established and entrenched in the literature the impression is that numerous subsequent writers and researchers may have adopted these attitudes without question. For example, by the 1940s this misunderstanding as to the composition of the glass frit used in the patent had spread across the Atlantic Ocean where Clement, writing in 1946, states that Heylyn and Frye made their porcelain by combining the kaolin with sand and potash.

Finally we note that the patent specifications have little to do with the 'French connection' as stated by Burton, if anything both the techniques and the use of a high-firing, refractory, kaolinite clay have more in common with both the Chinese and Meissen hard-paste ceramic practices (Ramsay & Ramsay in prep. a ,b, c).

An interesting exception to this developing negative mind-set regarding the 1744 patent was Hurlbutt (1926), who wrote the first comprehensive

monograph on Bow porcelain. He stood out from his contemporaries in that he appears to have consulted an original version of the patent wording and in addition, developed an independent view contrary to the prevailing fashionable ideas and dictates. Although accepting that only limited saleable porcelain was turned out between 1744 -1749, when the phosphatic second patent patent wares came into effect, Hurlbutt considers the patent as not unworkable and argues that the porcelain, comprising China clay imported from America and a glassy frit, would have initially had the character of opaque glass. This porcelain, in turn, he argues would have improved gradually as experience was gained to a glassy porcelain with high translucency and a creamy body and glaze. Of particular note, Hurlbutt recognises that the glaze associated with such wares would have been,

> ... composed of the same materials as the body, but with a larger proportion of the fusible glassy frit, to ensure the glaze fluxing at a lower temperature than the body.

an observation independently arrived at and confirmed by Ramsay et al. (2004a). Hurlbutt states that the clay utilized was a China clay but he advances no reason for this deduction. Also of interest is Hurlbutt's faith in the patent specifications,

> That at present no pieces of porcelain made of the frit and china-clay body at Heylyn's glass-house are known or identified, though, considering that the experiments went on for at least five years, there must have been a reasonable quantity of specimens made. These would be nearly all either white glazed porcelain pieces or decorated in underglaze cobalt blue.

Honey, a highly regarded ceramic historian, in his book, *English Pottery and Porcelain* (Honey 1933) comments that the 1744 patent specifies a clay brought from America and referred to as *uneka* by the native people. Honey states that nothing is known for certain of the porcelain made under this early patent and he acknowledges William Burton, whom he states was of the opinion that no sort of porcelain could have been made with the materials specified. In the third edition of Honey's *Old English Porcelain* (Honey 1977), revised by F. A. Barrett, the following is recorded,

> Under the patent a clay '... the product (*sic*) of the Chirokee nation in America, called by the natives 'unaker', was to be mixed with a frit made of ' pott ash, fern ash, pearl ash, kelp, or any other vegetable lixiviall salt', and 'sands, flints, pebbles or any other stones of the vitrifying kind'. Mr. William Burton has asserted, on technical grounds, that a paste so made would lack plasticity and that little, if any, porcelain could have been made under this patent. The 'unaker' (or china clay) was imported from America in 1743–4, doubtfully through the agency of one Andrew Duché, a potter from Savannah, in Georgia. No specimens of Bow china as early as 1744 can be identified, the earliest dated examples being of 1750, and it is doubtful whether anything was produced on a commercial scale at so early a date.

In this third edition, Franklin Barrett questions whether any wares were made according to the patent specifications, at least on a commercial basis. He also refers to the work of William Burton regarding the degree of plasticity of the paste supposedly used by the patentees. Lastly in a footnote to Andrew Duché he quotes the recent work by Graham Hood (Hood 1968) where it is concluded that Duché appears to have had no significant connection with Bow.

Fisher (1947: 23) speculates that no great amount of saleable ware was produced during the experimental period of 1744–1749, a view which appears to trace back to Hurlbutt (1926). In contrast however to Hurlbutt, Fisher (1965: 139) states that the clay added to the glass frit was a pipe-clay (ball-clay) to give the glassy artificial paste whiteness although no basis for the use of pipe-clay rather than China clay is provided. Possibly Fisher was confusing the 1744 patent with the 1749 patent of Thomas Frye, with the later patent specifically referring to pipe-clay, or he may have been influenced by Shaw (1837) and/or Burton (1906), who both suggest that Bow employed pipe-clay, sand from Alum Bay, and cullet.

Tait (1959: 8) in his significant exhibition publication on second patent Bow porcelains notes that the 1744 patent of Heylyn and Frye states,

> A new method of Manufacturing a certain material, whereby a ware might be made of the same nature or kind, and equal to, if not exceeding in goodness and beauty, China or Porcelain ware imported from abroad.

Based on the above wording Tait (1959, 1963) argues that the objective of the patent was to manufacture a material, which ultimately could be used for making porcelain wares. Tait (1965) continues this theme where he notes that the choice of wording in the 1744 patent reveals that by that date neither Heylyn nor Frye was yet able to make porcelain wares. Rather the invention patented was for the production of the material used in the construction of

porcelain wares and not for the wares themselves. Tait (1965: 43) writes,

> Very cautiously, the patent states that from this material porcelain wares 'might be made' — not that they could be made.

Yet strangely Tait (1963: 201) proposes that Heylyn and Frye, at the time of "hastily" seeking a patent, had not yet discovered how to make porcelain wares, "*at least not on a commercial scale*," thus suggesting the possibility that non-commercial wares could have been made by that date. Overall it appears that by concentrating on the wording in the patent,

> A new method of Manufacturing a certain material, whereby a ware might be made,

Tait may possibly have been quoting the patent out of context, because the patent continues in great detail specifying the proportions of the various components and detailing how such resulting wares were to be thrown on the wheel, cast into moulds, or imprinted into utensils and ornaments, with those thrown items afterwards turned on a lathe and burnished. Our interpretation on reading the patent as a whole is that the thrust of the wording is directed towards the making of wares and utensils and not merely a porcellaneous substance or material for that purpose.

Once Tait's thinking appeared in the literature it subsequently developed a life of its own and can apparently be traced into later works. Watney (1973) in a footnote to page 10 states,

> The phrase in the specification 'A New Method of Manufacturing a certain material whereby a ware might be made', suggests this urgency, as if only preliminary experiments had been made with the material for making porcelain.

Young (1999: 42) regards the patent specification as cautiously worded and Gabszewicz (2000: 15) states that the patent description for manufacturing a, "*material whereby a ware might be made*", is hesitant and uncertain and that the method of manufacturing a material does not specifically mention porcelain manufacture, but merely implies that this was the intention. Gabszewicz (2000: 15) further notes that although the patent called for the use of a China clay from North America, it is uncertain whether this clay was ever used. Subsequently Godden (2004a) states that the patent wording is tentative.

In 1963 Bernard Watney published his important book, *English Blue & White Porcelain of the 18th Century*. His comments on the 1744 patent contained in this publication have enjoyed considerable credence and influence over the last forty years and these comments are quoted,

> The specification of the first Bow patent enrolled on 5th April, 1745, claims the invention and perfection of 'a new method of manufacturing a certain material whereby a ware might be made of the same nature or kind and equal to, if not exceeding in goodness and beauty, china or porcelain ware imported from abroad'. It describes a recipe for blue and white using china clay called 'unaker' imported from North America. This kaolinic clay was intended to be used both in the glassy body and in the lead-free glaze. It is practically certain that as described this 'unaker' formula was unworkable, indeed it may have been patented merely as an attempt to monopolize the use of 'unaker' while experiments were being made to discover the secrets of Chinese hard-paste porcelain as had already been done at Meissen.

We note that based on the above quote it is difficult to deduce the grounds on which Watney was able to assert that he was practically certain that the *uneka* formula was unworkable. This assertion appears to hark-back to Burton (1902), but Watney gives no acknowledgement of these earlier observations and makes no reference to Burton's experimental work. Secondly, Watney suggests, without any apparent foundation, that the patent may have been taken out merely to monopolize the use of *uneka* while experiments were being undertaken to discover the secrets of Chinese hard-paste porcelain as had been done at Meissen. Yet again, these views appear to find parallels in comments by Burton (1906: 233),

> I have already pointed out, in my history of English porcelain, that no ware could have been made of the materials and the method specified in the patent, and though other writers have remarked that the specification was purposely vague, even to the point of being misleading, I am still of the opinion that when Helyn (*sic*) and Frye applied for the patent in 1744 they were really trying to protect a partially-learnt secret process; and the origin of the Bow porcelain, as of the other early English porcelains, is to be sought in the information communicated by wandering experts or experimentalists from one of the French factories.

In a strange manner there is possibly some truth in part of Watney's claims (though he was apparently

unaware of it at the time) because analogue wares produced according to the directions contained in the 1744 patent, using a refractory kaolinite clay (Cherokee clay) and a lime-alkali glass frit — not an alkali frit as specified by Church and attempted by Burton — are in fact hard-paste, high-firing porcelains, resistant to thermal shock, and quite dissimilar from French and English soft-paste porcelains being more akin to the hard-paste, or possibly more correctly high-firing porcelains of both Chinese and Meissen derivation (Ramsay et al. 2004a; Ramsay & Ramsay in prep. a, b, c). Such wares predate the widely acclaimed hard-paste porcelains {what Charleston and Mallet (1971) refer to as 'true' hard-paste} made by William Cookworthy by some twenty five years and in this connection it is worth recalling the suggestion by Binns (1898) that these Bow wares using such China clay would initially have been of a hard-paste nature and the prescient observations made by Arthur Lane (1958) in relation to the 'A'-marked group of porcelains,

> The body is much harder than that normal among the English soft-paste porcelains, including the soapstone porcelain of the Worcester-Liverpool group, and gives a modified conchoidal fracture. But it appears much less hard than the hard-paste porcelain made in Germany or under German influence. It is possibly a <hybrid> body, containing some kaolin, of a type made in Italy, especially in factories in the Venice area and at Doccia.

We suggest that by now an unstated circular argument may underlie much of the current interpretation of the patent; this being that because the patent was unworkable, vague, experimental, hesitant, and uncertain, this would explain why no derivative wares can be recognized and because no derivative wares can be recognized this would indicate that the patent was unworkable, vague, experimental, hesitant, and uncertain.

Adams (1973) suggests that it seems very unlikely that much porcelain was in fact made and that the patent may have been taken out merely to impede the way for would-be plagiarists, whilst Adams and Redstone (1981) record that the wording in the 1744 patent leaves one in no doubt that the idea of manufacturing china in east London was definitely under serious consideration. Subsequently Freeman (1982) records that whilst the precise materials used at Bow are not known, *uneka* clay imported from the American colonies was used in the early years.

Bradshaw (1992) in his book, *Bow Porcelain Figures circa 1748–1774*, in his treatment of the 1744 patent provides an excellent case study as to the current thinking on, and attitudes towards the patent. On page 14 Bradshaw reproduces an extract, which might appear to the casual reader be a quote from the 1744 patent itself. Bradshaw then concludes from this quote that the lack of more precise measurements in the patent suggests that the mix was experimental. Bradshaw then continues that,

> no items made from this formula have been identified and, indeed, it is unlikely any could successfully have been fired.

We note two aspects from this contribution; firstly the version of the patent supplied by Bradshaw is in fact Chaffers' less than adequate version, which has been circulating the literature since 1863, and secondly there has been a remarkable silence from the general ceramic community regarding the deductions arrived at by Bradshaw that the patent lacked more precise measurements thus suggesting that the recipe mix was experimental. It might appear that because Bradshaw's conclusions conform to the generally held view that the patent was hesitant, unworkable, imprecise, and at best experimental, little comment appears to have been made and we suspect that this may possibly be a case of the end result justifying the means.

The notion of '*experimental*' subsequently becomes '*highly experimental*' (Young 1999: 24) where he records that,

> An indication of the extremes that manufacturers would go to in order to obtain supplies in the earliest, highly experimental period is found in Bow's importation of china clay from Carolina in the American colonies in 1743/4.

Scarce (2000: 8) speculates that the 1744 patent was entered to secure the rights to use *uneka* clay and he notes that there is some evidence that American clay was actually used at Bow, although only for a very short period. Gabszewicz (2000: 15) apparently influenced by Tait's earlier writings states,

> The specification of the first patent claims the invention and perfection of 'a new method of manufacturing a certain material whereby a *ware might be made* of the same nature or kind and equal to, if not exceeding in goodness and beauty, china or porcelain ware imported from abroad.' This hesitant and uncertain way of describing the method of manufacturing a 'material' does not specifically mention porcelain manufacture, but implies that this was their intention. The recipe called for the use of a china clay called 'unaker' imported from North America, but whether this was used is not certain.

Hillis (2001) publishes part of the patent specifications, which apart from the odd variation from the patent's spelling and the elision of one or two words, is correctly based on the Eyre and Spottiswoode 1856 transcription. Although recognizing that the formula has been long held to be unworkable by modern commentators, Hillis notes that the recipe is not that dissimilar to the method used by John Dwight, which met with some degree of success, and if a China clay was used in the 1744 patent then there are grounds for accepting that 'A'-marked wares are early Bow. He also states that the lead-free glaze required by the patent and found to occur on 'A' -marked wares, supports this notion.

The most recent comment on the 1744 patent possibly lies with Godden (2004a: 71),

> It has been believed that no porcelain was ever made under this first patent* and you will note the wording is tentative and reads 'whereby a ware might be made'.
>
> * Recently (2002) *sic* — it has been suggested that the 'A' marked porcelains (see p.73) represent the earliest type of Bow porcelain, of the mid-1740s. The 'A' mark could relate to Arnold &Co.

Godden then supplies what appears to be an abridged quote taken from the patent. Part of this quote is indeed from the patent, part taken from Chaffers' incorrect version, and part might appear to be derived from some other source,

> a new method of manufacturing a certain mineral, whereby a ware might be made of the same nature or kind and equal to, if not exceeding, in goodness and beauty, china or porcelain ware imported from abroad... The material is an earth, the produce of the Cherokee nation in America, called by the natives Unaker... The articles are put into a kiln and burned with wood, called "biscuiting", if they are very white, they are ready to be painted blue...they are then dipt in glaze...

In a companion publication (Godden 2004b: 50) he accepts that American raw materials would have been used in small quantities but only during the early period.

In a comprehensive paper published detailing the 'A'-marked group of wares, the authors, Charleston and Mallet (1971) were the first to observe that based on a chemical analysis of a flange from an 'A'-marked teapot lid held in the collections of the Victoria and Albert Museum (V&A. C207A-1937), there could be some resemblance between porcelain material produced under the Bow first patent and that of the 'A'-marked group. However they continue,

> The difficulty in the way of this identification, however, is that this homogeneous small group bears no resemblance whatever, in shapes, details of potting, or enamelling, to the later Bow wares. This is difficult to credit when it is considered that the same management continued throughout the period at Bow. Nor is the 'A' mark explained, although it may be borne in mind that an 'A' mark in blue does occur on later Bow. On the whole, however, this hypothesis hardly stands up to scrutiny.

This emphasis on typological features at the expense of the composition is a feature, which has dominated English ceramic studies for many years. Subsequently Freestone (1996) likewise supports Charleston and Mallet's observation that 'A'-marked porcelain showed a good compositional correspondence with the Bow first patent, however he apparently resiled from a Bow attribution quoting the strong reservations expressed, for example, by Charleston and Mallet's on typological grounds. Whilst noting the correspondence between the Bow first patent and the 'A'-marked group, Freestone apparently opted for a Limehouse or Pomona attribution, even to the extent of speculating that the 'A'-marked wares might represent a special cargo of clay received at Limehouse. In two subsequent publications (Freestone 1999a, b) he states that the attribution of 'A'-marked wares is uncertain.

Of particular note is a footnote found in Emerson et al. (2000: 291) where Errol Manners is credited with recognizing the relationship between Heylyn and Frye and the 'A'-marked group. To our knowledge this might appear to be the first record in print where the 'trinity' is accepted, in that the 1744 patent is regarded as a viable recipe for porcelain wares, that those wares are the 'A'-marked group, and that the proprietors were Heylyn and Frye.

> A-marked porcelain as an early enterprise undertaken by Heylen and Frye, who would later establish the more commercial enterprise of Bow, is an idea first proposed to the author by Errol Manners of London, England. The use of kaolin from the Americas fits with the early Bow patent and the most recent scientific analysis of A-marked porcelain. Thomas Frye was more than capable of supplying the talent evident in the painting of the high-style wares. Certainly, porcelain decoration became a family occupation; his two daughters, their husbands, and probably his son as well were porcelain painters in the Bow factory.

In a series of papers dealing with the 1744 patent, Ramsay et al. (2001, 2003, 2004a, b) and Ramsay and Ramsay (2005a, b) adopt a somewhat different view of the 1744 patent from most other workers. They were struck with the clarity and deseriptive detail contained within the patent, in particular the description of the *uneka* elay employed and its geographieal loeation, the remarkable detail as to the proportions of elay to glass frit required for both body and glaze, the elear instruetions on firing such wares, and the eomments on various kiln-firing problems encountered by the patentees, Heylyn and Frye. What also struek them is the wealth of published material to be found mainly in the Amerienn literature dealing with Cherokee elay, the attempts by Josiah Wedgwood to obtain samples of this elay, and the experimental kiln-firings of Andrew Duché using inferred Cherokee clay (Watts 1913; Bayley 1925; Hommel 1934; Clement 1946, Gilmer 1947, 1948; Wells 1957; Goff 1959; Stuekey 1965; Hillier 1968; Hood 1968; Berkeley and Smith-Berkeley 1969; Mint Museum of Art 1976; Giannini 1981; Anderson 1986; Rauschenberg 1991a, b). In many instanees these referenees are rarely quoted in English publications with the possible exeeption of Tait (1959, 1963, 1965) and Watney (1963, 1973).

In their publications, the Ramsays and co-workers identify the most likely source of Cherokee elay in the eatehment of the Little Tennessee River, North Carolina, provide chemieal and mineralogieal parameters for this elay, discuss the likely discoverer of this clay, its transportation to London, and unequivocally specify the identity of those porcelains made using Cherokee elay or *uneka* aeeording to the 1744 patent. In addition, on firing analogue poreelain wares following the patent's specifications, they question the long-held mind-set that the patent is vague, hesitant, experimental, uneertain, tentative, unworkable, not worth the paper it is written on, and nothing but a sea of troubles. Colleetively these papers by Ramsay and eo-workers eonclude that the patent is, to the eontrary, well written and remarkably elear with regard to the reeipe (with the possible exception as to the specifications of the manufaeture of the lime-alkali glass frit), that the patent is direeted at the production of commereial poreelain wares, and that the patent is a highly signifieant doeument, which on the one hand relates to the 'A'-marked group of porcelains and on the other hand offers eireumstantial evidence linking the patent to Andrew Duehé and the Philadelphia eeramie tradition (Ramsay et al. 2004b).

In an address to the Royal Soeiety of Vietoria in June, 2005, Ramsay and Ramsay suggested that the 'A'-marked group of poreelains can arguably now be regarded as the most signifieant poreelain group to have been produeed in 18th eentury England and that these poreelains represent the English response to both Meissen and the Asiatie hard-paste poreelains. Features listed by Ramsay and Ramsay for this proposal inelude;

- the presenee of the 1744 patent, both dated and signed by five people, which details how these poreelains were made and without which it is doubtful that an attribution could have been aehieved;
- the remarkable entrepreneurial effort involved in transporting Cherokee elay some 600 kms to the coast of the Carolinas and thenee aeross the Atlantie Oeean to London, for a total of some 8,000kms. This transportation of the elay involved avoiding Indian objeetions, evading attaeks by 'Craekers,' and minimising eapture on the high seas by either the French or the Spanish. No other group of porcelain produeers, prior to Bow, went to such extraordinary efforts in soureing key ingredients for their wares;
- the notion that Bow first patent poreelains are the first high-firing, hard-paste, commercial porcelains to have been made in the English-speaking world using a refraetory China clay;
- the use of an assoeiated high-firing, Si-Al-Ca glaze whieh appears to have been fired eontemporaneously with the ceramic body, in the manner of Meissen;
- the absenee of lead as a signifieant eomponent in either the body or the glaze, again after the manner of both the Chinese and Meissen;
- the pereeived first use of slip-easting in English poreelains;
- the remarkable level of enamelling and the first to introduee Meissen- and/or Asiatie-derived deeorative themes to English porcelain; and
- the distinet possibility that the 'A'-marked group of porcelains may owe a eonsiderable, yet unrecognized, debt to the *Philadelphia ceramic tradition* out of colonial Ameriea.

DISCUSSION

In this account we have investigated various views, notions, and attitudes associated with the 1744 patent of Heylyn and Frye. Several themes or strands,

which both individually and collectively have tended to diminish, if not marginalize, the stature of this patent are identified and discussed. The first theme dates back to 1837 when Shaw stated that early Bow wares comprise a body whose recipe was pipe-clay, cullet, and Alum Bay sand which was coated with a lead-based glaze. We have to date been unable to establish the basis for this recipe in regard to Bow, though we note that such a recipe may approximate early triangle period Chelsea wares. Inexplicably, this recipe reappears some sixty-five years later when Burton proposes such a composition for early pre-second patent Bow wares. In 1863 William Chaffers' imprecise version of the 1744 patent was published. This apparent transcript has become so embedded in the literature through repeated reprints that it now at times replaces the original version, or contributes to what might be described as composite transcriptions of portions of the patent recipe. Use of the Chaffers' version of the 1744 patent has in some instances in our opinion, led to incorrect assertions that the patent was apparently deficient in precise measurements and hence was experimental.

The third aspect relates to the assumed composition of the glass frit used in the patent. Burton (1902) accepted Church's claim that the glass comprised one part silica and one part potash and in his attempted experimental replication of analogue 1744 patent wares, Burton reports that the patent recipe was unworkable and not worth the paper it was written on. We would contend that the composition of the glass frit proposed by Church and replicated by Burton is incorrect and is not in accord with either the patent wording or common sense. Church (1911), a quarter of a century after he first proposed the potash-glass recipe persists with this composition even though a decade earlier Burton had demonstrated experimentally that such a recipe composition was 'unworkable.' This notion that the 1744 patent recipe was unworkable has reappeared in numerous subsequent works, the most influential being Watney (1963, 1973) who in addition proposes, without any apparent justification, that the 1744 patent may have been a 'front' while experiments leading to the making of 'true' hard-paste porcelain were brought to fruition. We suggest that in addition, an unstated circular argument may underlie and support the assertion that the *uneka*-based formula was unworkable, namely that because the patent was unworkable this would explain the apparent absence of porcelain wares made following the patent specifications and because no such products of this patent could be recognized this was likely to reflect an unworkable patent recipe. It is tempting to speculate that it is this inferred circular reasoning which is one of the reasons, albeit unstated, why there has been such a reluctance to accept the 'A'-marked porcelain group as the legitimate products of the 1744 patent and manufactured by Heylyn and Frye in East London.

The fourth component discussed relates to Tait's claim that the patent was designed merely to make a porcellaneous substance or material and not porcelain wares themselves, at least not on a commercial scale. We suggest that this view of the patent may possibly have been taken out of context. Tait's use of the word "*cautious*" with regard to the patent has been quickly adopted and subsequent writers have used words such as cautious, tentative, hesitant, and uncertain to describe the patent wording.

Based on the wording of the 1744 patent, the work of fellow ceramic historians (Lane 1958; Charleston and Mallet 1971; Mallet 1994; Freestone 1996) and research to date by Ramsay, Ramsay, and coworkers, we suggest that far from being unworkable, experimental, or hesitant, the 1744 patent of Heylyn and Frye is one of the major documents in English ceramic history. This patent directly relates to what we would contend are the first commercial porcelains made in the English-speaking world, namely the 'A'-marked group. The clay required is a refractory China clay and as noted by Hurlbutt (1926) and Ramsay et al. (2004a), Heylyn and Frye in a brilliant stroke appear to have modified the glaze composition and its application so that it could be used as a crude but effective optical pyrometer. This firing to the porous biscuit (~950°C) followed by the glazing and then firing to top temperature (~1,280°C) (Ramsay et al. 2004a) appears to have been influenced by Meissen kiln-firing procedures (Ramsay & Ramsay in prep. a, b). We question any suggestion that the recipe was derived from the French soft-paste porcelain tradition, as suggested by such writers as Burton and Solon. Moreover these high-firing, hard-paste wares predate Cookworthy's 'true' hard-paste porcelains by some twenty five years and consequently we suggest that these Bow first patent porcelains represent the hitherto unrecognized earliest English equivalents to Meissen porcelain and the Oriental.

It has now been demonstrated (Freestone 1996; Ramsay et al. 2003, 2004a) that whoever was making the 'A'-marked group of porcelains was replicating the 1744 patent with regard to the starting materials, the composition of the body, the composition of the glaze, and the resultant mineralogy of the

subsequently fired porcelain body. The most reasonable and logical deduction based on this evidence is that it is in fact the patentees themselves, Heylyn and Frye, who were the proprietors responsible of the 'A'-marked group of porcelains and that such wares were fired in East London on a commercial basis by around 1743 (Daniels 2003; Ramsay et al. 2004a). We can find no obvious reason why these two very significant figures in the field of early English porcelain development, together with three other witnesses — two of whom were directly related to Edward Heylyn — should go to the trouble of entering a detailed ceramic patent which they had no intention of prosecuting. The specifications of this patent were 'enrolled' in April 1745 and the patent clearly refers to a preceding period of active development and experimentation. Barry Taylor (pers. com. 2005) comments that there is a distinct typological continuity between 'A'-marked wares and those of the second patent, particularly in decoration and palette, whereas the non-conformity in form and potting strongly reflects the change in the raw materials, body type, and techniques that occurred between the two patents.

From the foregoing it has been surmised that the colonial American potter, Andrew Duché played a highly significant role in recognizing the ceramic properties of Cherokee clay or *uneka*, transporting samples out of the Little Tennessee River catchment in the Southern Appalachians, conducting experimental firings of this clay by at least early 1741, if not earlier in Savannah, and introducing Edward Heylyn and possibly George Arnold to this clay, his experimental porcelains, and to at least some of the associated technology required for dealing with high-firing, refractory kaolinite clay (Savage 1970: 336; Ramsay et al. 2001; Ramsay et al. 2004b; Ramsay and Ramsay in prep. b). To date the influence of the *Philadelphia ceramic tradition* on the development of the earliest hard-paste porcelains in the English-speaking world has not been fully appreciated.

We suggest that it may now be timely to reconsider the pre-eminent role enjoyed by Chelsea to date. This role has been built on the assumption that Chelsea was the first commercial English porcelain manufactory, the quality of its soft-paste porcelain, the high standard of the potting, and the quality of the on-glaze decoration. Traditionally Chelsea has been regarded as assuming a leadership role in transmitting European ceramic decorative styles, including Meissen into the English idiom. Possibly the prevailing view as to one of the major differences between the attitudes of the proprietors of Bow second patent wares and the Chelsea proprietors is encapsulated by Stanley Fisher (1965: 139).

> When the Bow porcelain-making factory was founded about 1744 by Thomas Frye and Edward Heylyn the intention was to make a durable, sensibly decorated domestic ware, and not to try to rival the splendours of the ware made at neighbouring Chelsea, apart from an occasional colourfully painted service, and for figures which had to be made to meet an overwhelming demand.

We propose that the Bow first patent wares were directed first and foremost at the luxury or 'high-end' of the market and that this technically and decoratively brilliant porcelain group acted as the catalyst for the appearance and growth of other English manufactories (including Chelsea), which within a decade of 1744 blossomed into some ten competing concerns.

We conclude with the following points:

1. It is proposed that the 1744 patent of Heylyn and Frye is one of the major documents pertaining to the Anglo-American ceramic industry, yet the significance and stature of this patent has been apparently diminished and marginalized over the last 100 years or so, by way erroneous transcriptions of the patent itself, incorrect assertions about the chemical makeup of the patent recipe, claims that the patent recipe was almost certainly unworkable, possible circular arguments, and deductions regarding the patent, which possibly may have been taken out of context, thus leading to the belief that the patent was entered merely to manufacture a porcellaneous material and not wares themselves.
2. Some researchers, to varying degrees, have not accepted these negative views and have suggested that the patent may not have been entirely unworkable with wares of some kind being turned out for a short period. Possibly the most striking examples being Hurlbutt (1926) and Manners as quoted in Emerson et al. (2000).
3. We suggest that the acceptance of the importance and veracity of the 1744 patent is a necessary prerequisite for a better understanding of the events relating to the earliest years of the porcelain industry in the English-speaking world.
4. The 'A'-marked group of porcelains, which we regard as the product of the 1744 patent, is remarkable on account of its high-firing characteristics, its resultant hard-paste body, and the

startling standard of the on-glaze decoration. In addition the use of refractory China clay, the inferred bisque firing of the glaze and the body together, and the employment of a Si-Al-Ca body and glaze lacking the addition of lead suggest links with Meissen techniques. We agree with Tiffin (1874) and Daniels (2003) that it was Bow first patent wares, which were referred to in the Vincennes Privilege awarded to Charles Adams on July 24th, 1745.

5. We believe that the 1744 patent acts as the vital link with the 'A'-marked group of porcelains and that it can now be regarded as scientifically proven that whoever was making this remarkable group of porcelains was replicating the patent specifications with regard to starting materials, body and glaze compositions, and the resultant mineralogy of the high-fired body.
6. Numerous authorities (Burton 1906; Watney 1963, 1973; Fisher 1965; Savage 1970; Spiro 1998; Young 1999; Godden 2004a,b) unanimously credit William Cookworthy and his patent of 1768 as marking the introduction of a 'true' hard-paste porcelain to Great Britain. Whilst in no way wishing to detract from Cookworthy's significant contribution, we point out that the 1744 patent and the products of this patent predate Cookworthy's acclaimed contribution by a quarter of a century, yet because of the assumed negative aspects attached to the Heylyn and Frye patent, its significance has been overlooked or marginalised.
7. The 1744 patent offers circumstantial evidence which links the colonial American potter, Andrew Duché, to Edward Heylyn and possibly George Arnold, both as the supplier of Cherokee clay and possibly as the source for at least some of the technology required to produce high-firing porcelains using this refractory China clay. On this basis we suggest that the *Philadelphia ceramic tradition* and its influence on early hard-paste, high-firing porcelains needs to be re-assessed.
8. It might appear that the importance of the Chelsea porcelain concern *vis-à-vis* Bow needs to be re-evaluated. Contrary to popular belief, the Bow proprietors set out from the outset to produce a range of luxury porcelains (*objets de luxe*), in part inspired by decorative features derived from Meissen, thus predating the onset of Chelsea's Meissen period by some 5 to 6 years. Moreover the technical and artistic brilliance of these hard-paste porcelains surpasses that of early Chelsea soft-paste triangle period wares.
9. We propose that by around 1743 the Bow proprietors were producing high-fired, hard-paste, commercial porcelains using an imported China clay from the Carolinas with decorative elements in part derived from the London theatre, the Orient, and Meissen (Ramsay & Ramsay 2006). The decorative and compositional features of these ceramics, coupled with the proposed early date of manufacture and the remarkable entrepreneurial skill shown by the proprietors, lead us to believe that the 'A'-marked group of porcelains represents the English answer to Meissen and Oriental hard-paste porcelain and consequently is arguably the most significant group to have appeared in 18th century England. In addition the patent, which describes the manufacture of these porcelains, is a landmark document in Anglo-American ceramic history.

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TAXONOMY OF AN OSTRACODE ASSEMBLAGE FROM THE MIDDLE MIOCENE WUK WUK MARL, GIPPSLAND, VICTORIA

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JOHN V. NEIL, 2006. Taxonomy of an ostracode assemblage from the Middle Miocene Wuk Wuk Marl, Gippsland, Victoria. *Proceedings of the Royal Society of Victoria* 118 (1): 35-63. ISSN 0035-9211.

Fifty-six taxa are recorded from the Middle Miocene Wuk Wuk Marl, Gippsland Basin, Victoria. One new species, *Parakrithella hentyensis*, is described. Thirty-nine species previously recorded from mid-Tertiary and Recent southeastern Australian assemblages are listed, together with comments on their geographic and stratigraphic distribution in this region. Some of these species (*Neobuntonia batesfordiense, Hermanites glyphica, Loxoconcha propunctata, Dumontina cratis, Oculocytheropteron microfornix, Cletocythereis rastromarginata, Polycope demulderi, Uroleberis minutissima*, and *Pokorneyella* sp.) are discussed at greater length. The commonest species suggest a general similarity of this assemblage to the other assemblages from the region. The proportion of rare species in the assemblage (65%) is discussed, and its significance in adequately describing the assemblage is stressed.

Keywords. Ostracoda, Middle Miocene, taxonomy, Gippsland Basin.

THE Foraminiferida of the Tertiary sediments of the Gippsland Basin were monographed by Carter (1964). He used the occurrence of key species to establish a series of faunal units to clarify the stratigraphic relationships of the sedimentary deposits of the basin. Carter's "Faunal Units" have thus been of value in defining the biostratigraphy of the Tertiary strata in Gippsland for forty years. More recent work has established that the Wuk Wuk Marl, which this paper examines, lies in the Middle Miocene in the N8 zone (Li & McGowran 2000). Discussion of the age of these sediments continues (Holdgate & Gallagher 1997; Darragh 2001), but an assignment to early Middle Miocene (N8) appears still to be acceptable. The microfauna of these strata is diverse and well-preserved, but the Ostracoda have received limited attention (Chapman 1926; McKenzie 1974; Woodall 1986). This study is based on an ostracode assemblage from the Wuk Wuk Marl, sampled at its type locality ("Skinner's"), at water level on the left bank of the Mitchell River upstream from Bairnsdale (SW corner, Allotment 29A[1]), Geological Survey of Victoria Locality F31, Museum Victoria Locality PL 3054. Neil (1995) has made comparisons between this assemblage and other Oligocene and Miocene assemblages from southeastern Australia in terms of palaeobiogeography. The present paper describes the assemblage and extends these comparisons with references to other southeast Australian assemblages.

PREVIOUS WORK

Southeast Australian ostracode faunas received limited attention until the last three decades. Chapman's work (Chapman 1910, 1914, 1926; Chapman & Crespin 1928) remained the only studies of Tertiary Ostracoda for almost 40 years until McKenzie began a series of studies extending over the next 30 years. His broad-ranging work began with studies of Recent Ostracoda (McKenzie 1965, 1967) and then shifted to Tertiary faunas (McKenzie 1974, 1977, 1978, 1981; McKenzie & Neil 1983; McKenzie & Peypouquet 1984). Most recently he collaborated with Richard and Ewa Reyment on further taxonomic studies of coastal faunas from Victoria and South Australia (1990, 1991, 1993). McKenzie's seminal work has been expanded by Warne (1986, 1987, 1988, 1990a, 1990b, 1996, 2002), Neil (1994, 1995, 1997, 2000a, 2000b), Majoran (1995, 1996) and others. A monograph by Jellinek & Swanson (2003), whilst treating mostly living specimens in samples from the Tasman Sea and Southern Ocean, revises and clarifies the taxonomy of a number of important genera dealt with in this paper. Ayress (1993a, b; 1995,1996; Ayress, Barrow, Passlow & Whatley, 1999; Ayress & Warne, 1993) have also made a significant, though indirect, contribution to the taxonomy of southeast Australian faunas through papers on New Zealand and southeast Australian assemblages.

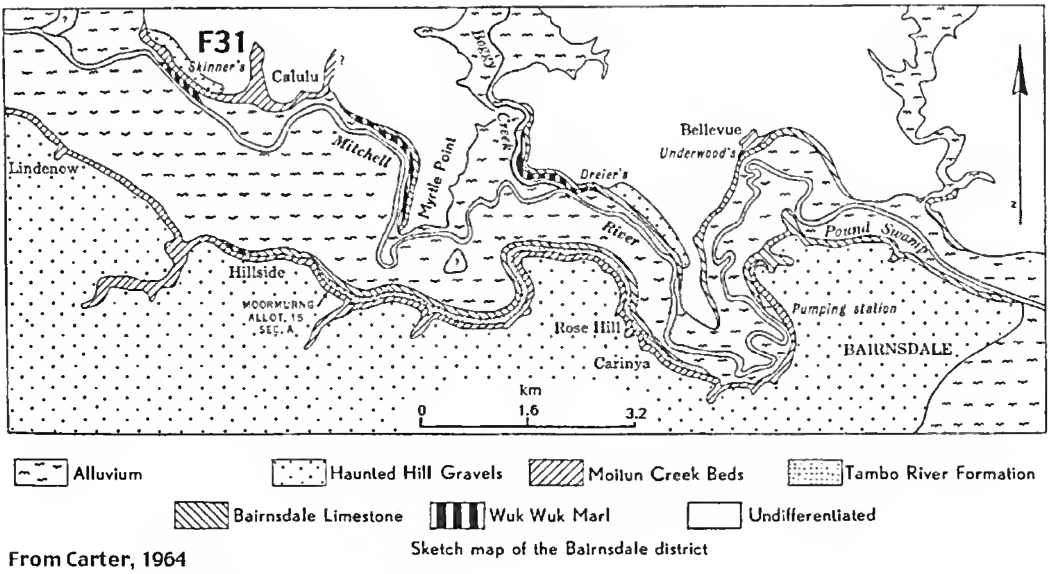

Fig. 1. Location of "Skinners" (Fossil Locality F31)

SYSTEMATIC PALAEONTOLOGY

The classification followed here is generally that put forward by Hartmann & Puri (1974). References to taxonomy have been checked, where possible, from Kempf's compendia *Index and Bibliography of Marine Ostracoda* (1988 and later years). All specimens are from the specified locality (F31), and are of late Early Miocene (N8) age. The specimens are housed in the Invertebrate Palaeontology Collection of Museum Victoria, and are identified by numbers prefixed P. Abbreviations used: RV — Right valve; LV — Left valve; Cara. — Carapace.

Subclass OSTRACODA Latreille, 1806
Order PODOCOPIDA G.W.Müller, 1894
Suborder CLADOCOPA Sars, 1866
Family POLYCOPIDAE Sars, 1866
Polycope Sars, 1866

Type species. Polycope orbicularis Sars,1866

Polycope demulderi Sissingh, 1972

Polycope demulderi Bonaduce, Ciliberto, Masoli, Minichelli & Pugliese, 1982: 349, pl.1, fig.3.
Polycope sp.1 McKenzie, 1974: 160, pl.1, fig.1.
Polycope sanctacatharinae Whatley & Downing, 1983: 387–388, pl.8, figs 20, 21. — Warne, 1990a: 60–62, figs 2A-2D. — Neil, 1992: 45–6, pl.1, fig.A

Figured specimen. Fig.2A (P146979)

Remarks: These specimens are clearly conspecific with Whatley and Downing's species *Polycope sanctacatharinae* (1983), which the writer regards as a junior synonym of *P.demulderi* Sissingh, 1972. Warne (1990a) has already drawn attention to the perceived similarity with Sissingh's species. *Polycope demulderi* has also been encountered by the writer in early Middle Miocene assemblages from the Batesford Quarry, Muddy Creek in southwestern Victoria and the Leigh River, south central Victoria. Warne suggests that *Polycope* sp.1 of Whatley and Downing (1983) may be a variant of *P.demulderi*. I have encountered this alleged variant in an assemblage from Batesford Quarry, but suggest it may be a new species.

Measurements: P146979: L=0.46, H=0.34

Material: 3 specimens

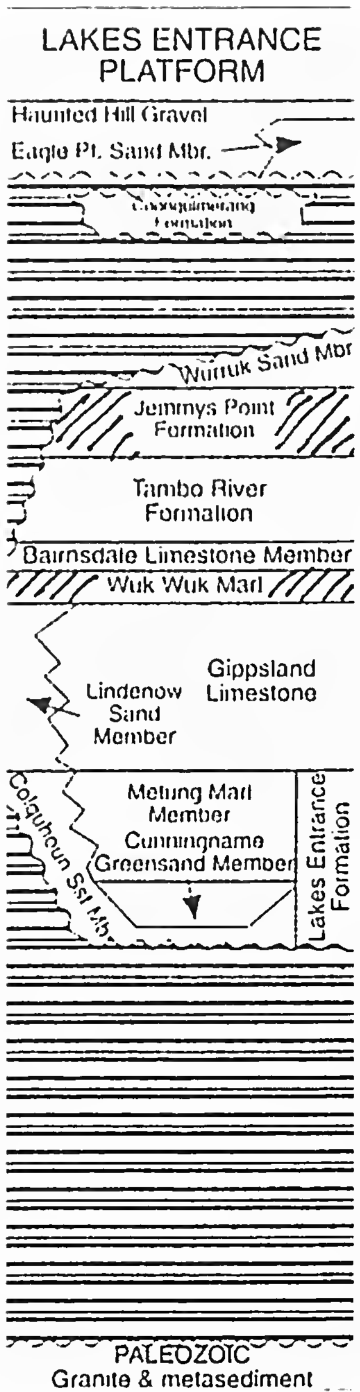

Fig.2

* Section sampled

Fig. 2. Generalised section showing stratigraphic units.

Suborder PLATYCOPA Sars, 1866
Family CYTHERELLIDAE Sars, 1866
Cytherella Jones, 1849

Type species. Cytherina ovata Roemer, 1840

Cytherella paranitida Whatley & Downing, 1983

Cytherella paranitida Whatley & Downing, 1983: 385, pl.8, figs 4,5 . — Neil, 1992: 50, pl.1, fig. J. — Ayress, 1993: fig. 4M

Figured specimen. Fig.2B Female LV (P146980)

Remarks. Although these specimens are slightly sinuous on the ventral margin, the shape, size and muscle scar pattern are consistent with *C. paranitida* . The characteristic micropunctation at either end of the valve is clearly present. The anterior and posterior margins of the figured specimen show slight reticulate development. A total of 6 specimens in an assemblage of >500 underlines the rarity of the species.

Measurements. P146980: L=0.80, H=0.50

Material. 6 specimens, including 1 carapace.

Cytherella sp.cf. Cytherella gullrockensis
McKenzie , Reyment & Reyment, 1991

Cytherella sp. McKenzie, 1979: 90, pl.1, fig.3. - Whatley & Downing, 1983: 385, pl.8, figs 6,7,8. — McKenzie, Reyment & Reyment, 1991: 138, pl.1, fig.8.
Cytherella gulrockensis McKenzie, Reyment & Reyment, 1991: 137–8, pl.1, figs 2,4.
Cytherella sp.B Neil, 1992: 52, pl.2, fig.B.

Figured specimen. Fig.2C (P146981)

Remarks. It is probable that all the specimens synonymised above are conspecific, but it is not clear that they fit the description given in McKenzie et al. (1991) which allows a distinctly ovate form for the females, a factor consistent with all of these specimens. However, their figures do not bear this out, since they refer to the elongate specimen (pl.1, fig.2) as a female — it is a male. Their figure (pl.1, fig.8) is likely to be a female of *C.gullrockensis* . The small number of specimens available here (all females) makes it unwise to attribute them unequivocally to McKenzie et al.'s species. It is rare in this assemblage.

Swanson, Jellinek & Malz (2005) erect a new genus, *Inversacytherella* in which they include *Cytherella gullrockensis* on the basis of a reversed valve ratio.

Measurements. P146981: L=0.92, H=0.62

Material. 5 specimens.

Suborder PODOCOPA Sars,1866
Family BAIDIIDAE Sars, 1885
Neonesidea Maddocks, 1969

Type species Triebelina schulzi Hartmann, 1962

Neonesidea chapmani Whatley & Downing, 1983

Neonesidea chapmani Whatley & Downing, 1983: 349–351, pl.1, figs 1–4. — Warne, 1988: 17, figs 9C, D. — Neil, 1992: 62, pl.3, fig.F. — Ayress, 1995: 900 (Listed).

Figured specimen, Fig.2D (P146982)

Remarks. This species occurs on both sides of the Tasman, but with a later range in Australia. *N. chapmani* occurs in Late Eocene and Oligocene sediments in New Zealand (Ayress 1993a, 1995). In Victoria, Warne (1988) gives its range from late Early Miocene to early Late Miocene. The posterior denticulation referred to by Warne (1988) is clearly visible. The sharp variations between LV and RV are evident in a carapace (not figured).

Measurements. P146982: L=0.68, H=0.42

Material. 80 specimens

Neonesidea australis (Chapman, 1914)

Bairdia australis Chapman, 1914: 31–2, pl.6, fig.7.
Neonesidea australis Whatley & Downing, 1983: 351, pl.1, figs 5–6. — Warne, 1988: 16, figs 9A, 9B. — McKenzie et al. 1991: 140,142, pl.1, fig.13. — Neil, 1992: 61–62, pl.3, fig.E. — Yassini, Jones & Jones, 1993: 384, pl.1, figs 9, 10.

Figured specimen. Fig.2E (P146983)

Remarks. These specimens are classified on the basis of shape alone, since muscle scar patterns are obscured.

Measurements. P146983: L=0.96, H=0.68

Material. 9 specimens.

Neonesidea austrotumida McKenzie et al. 1993

Neonesidea austrotumida McKenzie, Reyment & Reyment, 1993: 79–80, pl.1, figs 11, 12.

Remarks. Two LV specimens, with muscle scars clearly exposed, extend the range of this species from the Late Eocene to the Early Miocene. Not figured.

Material. 2 specimens (P146984).

Neonesidea sp.A

Figured specimen. Fig.2I (P146985)

Remarks. These large specimens are more attenuated posteriorly, with an acute termination, than other *Neonesidea* species from Australia, except for *Neonesidea* sp.A (Neil 1992) which has a similar general shape.

Measurements. P146985: L=1.2, H=0.70

Material. 3 specimens.

Neonesidea sp.B

Remarks. These specimens are characterised by a dorsal margin with two angulations, and an acutely angled posterior. The shape is similar to that of *N. chapmani* , but the highest dorsal angle is anterior to the midline, and the ventral margin is directed upwards towards the posterior because of a greater angulation near the anterior third of the valve. Not figured.

Material. 2 RVs (P146986)

Paranesidea Maddocks, 1969

Type species. Paranesidea fracticorallicola Maddocks, 1969

Paranesidea barwonensis Warne, 1986

Paranesidea barwonensis Warne, 1986: 42–43, figs 3A-I, 4A-B. — Neil, 1992: 68, pl.4, fig. F.

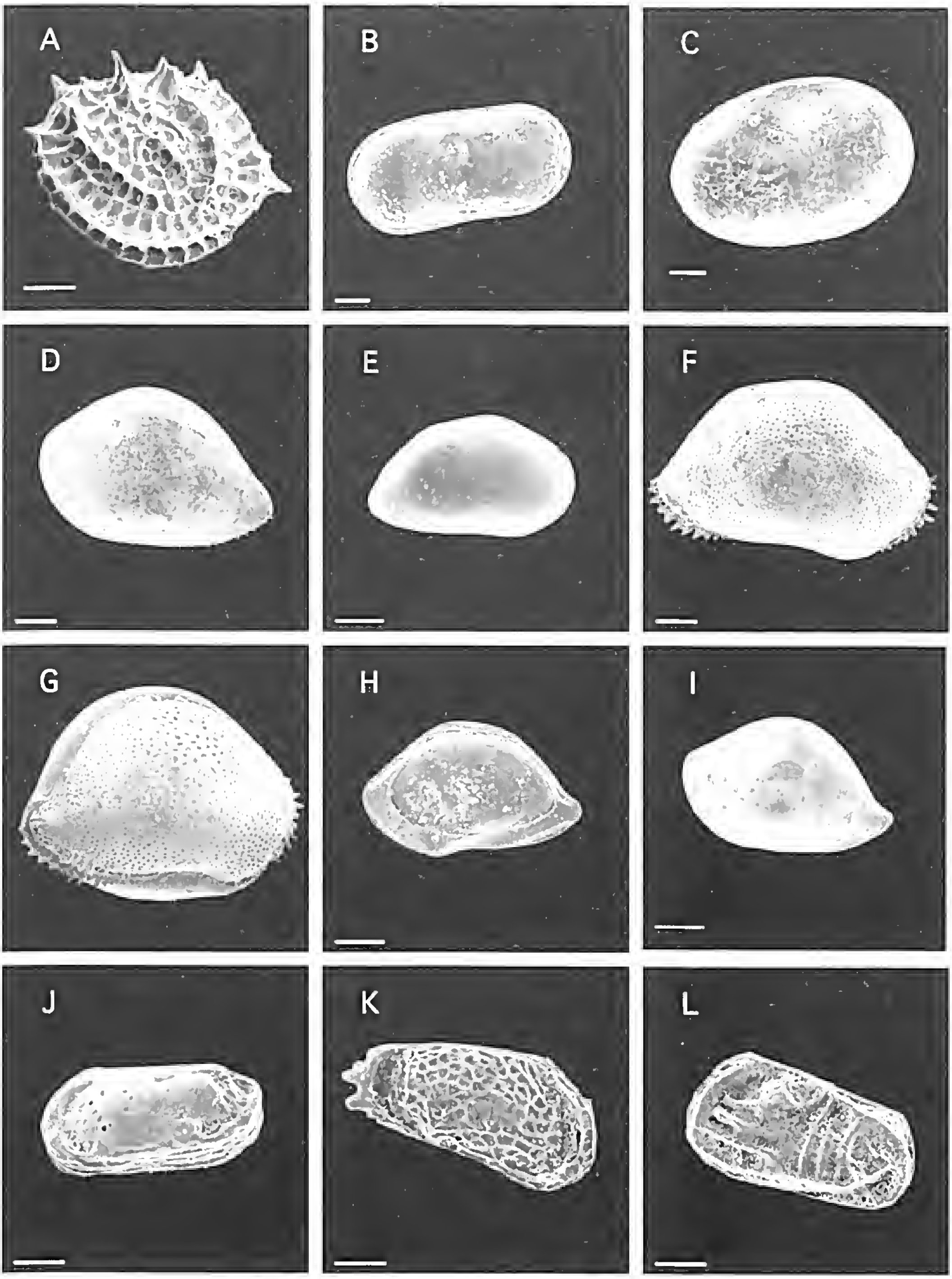

Fig. 3. A. *Polycope demulderi* 0.06mm. B. *Cytherella paranitida* C. *Cytherella* sp.cf. *C.gullrockensis* D. *Neonesidea chapmani* E. *Neonesidea australis* 0.2mm. F. *Paranesidea barwonensis* G. *P.barwonensis* (Cara.) Oblique view — no scale. H. *Bairdoppilata fyansfordensis* 0.2mm. I. *Neonesidea* sp.A 0.2mm. J. *Munseyella bungoona* (Ventrolateral view) 0.07mm. K. *Swansonites* sp.cf.*intermedia* 0.07mm. L. *Vandiemencythere gunyoungensis.* 0.07mm. For figures of ostracodes, the length represented by the scale bar is 0.1mm. unless otherwise stated.

Figured specimens. Fig.2F (P146987); 2G (Cara.) (P146988)

Remarks. These specimens show varying levels of preservation, and occur within the stratigraphic range already established by Warne (1986).

Measurements. P146987: L=0.80, H=0.48; P146988 (Not measured)

Material. 13 specimens including 4 carapaces.

Bairdoppilata Coryell, Sample & Jennings, 1965

Type species. Bairdoppilata martyni Coryell, Sample & Jennings, 1935

Bairdoppilata fyansfordensis Warne, 1988

Bairdoppilata fyansfordensis Warne, 1988: 20–22, figs 8E,F,K,L; 10H-N.
Bairdoppilata(?) cf. *fyansfordensis* McKenzie, Reyment & Reyment, 1993: 80.

Figured specimen. Fig.2H (P146990)

Remarks. There are only two specimens in this population of over 100 bairdiids. Only a small number of carapaces occur, so that the characteristic posterior and anterior teeth of *Bairdoppilata* would have been evident in the other specimens, since the carapaces belong to *Neonesidea* species.

Measurements. P146990: L=0.80, H=0.48

Material. 2 specimens.

Family CYTHERIDAE Baird, 1850

Microcythere G.W.Müller, 1894

Type species. Microcythere inflexa G.W.Müller, 1894:328, pl24, figs 30–32,40–42,48,50.

Microcythere sp.

Remarks. Internal features not known. Shape indeterminate. Smooth surface.

Material. One specimen, a carapace. Not figured. (P146992).

Family PECTOCYTHERIDAE Hanai, 1957
Munseyella van den Bold, 1957

Type species. Toulminia hyalokystis Munsey, 1953

Munseyella bungoona McKenzie, Reyment & Reyment, 1993

Munseyella bungoona McKenzie, Reyment & Reyment, 1993: 96–97, pl.4, figs 14–17; pl.8, fig. 10.
Munseyella sp.cf.*bungoona* Neil, 1997: 174–176, figs 2G, J; 9C.

Figured specimen. Fig.2J (P146993)

Remarks. This single carapace extends the range of this species from Late Palaeocene (Neil 1997) and Eocene (McKenzie et al. 1993) to late Early Miocene (N8). The rarity of occurrence contrasts with the abundant pectocytherinids in the earlier assemblages from Pebble Point and Castle Cove referred to above.

Measurements. P146993: L=0.42, H=0.18

Material. 1 carapace.

Swansonites Milhau, 1993

Type species. Munseyella aequa Swanson, 1979.

Swansonites sp.cf. **Swansonites intermedia** Milhau, 1993

Keijia sp.A Neil, 1992: 89, pl. 7, fig. 1.

Figured specimen. Fig.2K (P146994)

Remarks. This specimen is quite close to *S. intermedia* from which it differs most in the prominence of the posterior spines, and the ventral reticulation which has an elongated network, rather than the subcircular pattern of *S. intermedia.* Neil (1992) has noted this species from the late Early Miocene of the Muddy Creek Marl on Grange Burn, southwest Victoria.

Measurements. P146994: L=0.48, H=0.24

Material. 1 specimen.

Species	No.	%
01. *Neonesidea chapmani*	80	16.1
02. *Neohuntonia batesfordiense*	59	11.9
03. *Uroleberis minutissima*	36	7.3
04. *Hermanites glyphica*	30	6.1
05. *"Hermanites" lungulata*	23	4.6
06. *Loxoconcha propunctata*	23	4.6
07. *Dumontina cratis*	22	4.4
08. *Q.(Hornibrookellina) hentyensis*	22	4.4
09. *Chapmanella flexicostata*	21	4.2
10. *Bradleya(Bradleya) kincaidiana*	19	3.8
11. *Quadracythere* sp.aff.*Q.spica*	19	3.8
12. *"Hermanites" thomasi*	16	3.2
13. *Paranesidea barwonensis*	13	2.6
14. *Cletocythereis caudispinosa*	11	2.2
15. *Neonesidea australis*	9	1.8
16. *Oculocytheropteron microfornix*	9	1.8
17. *Loxoconcha mcgowrani*	9	1.8
18. *Cytherella paranitida*	6	1.2
19. *Cytherella* sp.cf.*C.gullrockensis*	5	1.0
20. *Parakrithella hentyensis*	5	1.0
21. *Hanaiceratina balcombensis*	4	0.8
22. *?Actinocythereis* sp.	3	0.6
23. *B.(Quasibradleya)* sp.cf.*(Q.)cemazea*	3	0.6
24. Campylocytherine trachyleberid	3	0.6
25. *Neonesidea* sp.A	3	0.6
26. *Pokornyella* sp.	3	0.6
27. *Polycope demulderi*	3	0.6
28. *Quadracythere* sp.	3	0.6
29. *Roundracythere phaseolus*	3	0.6
30. *Xestoleberis* sp.	3	0.6
31. *Bairdoppilata fyansfordensis*	2	0.4
32. *Cytheralison pravacauda*	2	0.4
33. *Neonesidea austrotumida*	2	0.4
34. *Neonesidea* sp.B	2	0.4
35. *Trachyleberis paucispinosa*	2	0.4
36. *Argilloecia* sp.	1	0.2
37. *B.(Quasibradleya)* sp.cf.*(Q.)janjukiana*	1	0.2
38. *Bythoceratina* sp.	1	0.2
39. *Bythocypris* sp.	1	0.2
40. *Cletocythereis rastromarginata*	1	0.2
41. *Eucytherura delta*	1	0.2
42. *Kangarina* sp.1	1	0.2
43. *Kangarina* sp.2	1	0.2
44. *Krithe nitida*	1	0.2
45. *Macrocypris* sp.1	1	0.2
46. *Macrocypris* sp.2	1	0.2
47. *Microcythere* sp.	1	0.2
48. *Munseyella bungoona*	1	0.2
49. *Paranesidea* sp.	1	0.2
50. *Semicytherura* sp.	1	0.2
51. *Semicytherura illerti*	1	0.2
52. *Spinobradleya nodosa*	1	0.2
53. *Swansonites* sp.cf.*(S.)intermedia*	1	0.2
54. *Trachyleberis floridus*	1	0.2
55. *Vandiemencythere gunyoungensis*	1	0.2
Total number of specimens	**496**	**100**

Table 1. Assemblage composition

Family LEPTOCYTHERIDAE Hanai, 1957
Vandiemencythere Ayress & Warne, 1993

Type species. Vandiemencythere gunyoungensis Ayress & Warne, 1993

Vandiemencythere gunyoungensis
Ayress & Warne, 1993

(Leptocytheridae) sp.1 Warne, 1987: 442.
Pectocytherinid gen.nov. et sp. Neil, 1992: 93–94, pl.8, fig.E
Vandiemencythere gunyoungensis Ayress & Warne, 1993: 34–35, text-fig.1, pl.1, figs 1,3,6.

Figured specimen. Fig.2L (P146995)

Remarks. Although not well-preserved, this specimen is clearly *Vandiemencythere gunyoungensis* with its distinctive pattern of ridges and antero-dorsal swelling. This occurrence in the late Early Miocene (Batesfordian) of the Wuk Wuk Marl of Gippsland, and another in the early Middle Miocene (Balcombian) Muddy Creek Marl of southwest Victoria (Neil 1992) extend the range and provenance of this species.

Measurements. P146995: L=0.42, H=0.22

Material. 1 specimen.

Family EUCYTHERIDAE Puri, 1954

Rotundracythere Mandelstam, 1958

Type species. Eucythere rotunda Hornibrook, 1952

Rotundracythere phaseolus Neil, 2000

Rotundracythere phaseolus Neil, 2000b: 130–131, figs 3A-H.

Figured specimen. Fig.3A (P146996)

Remarks. Rotundracythere phaseolus was first described from the Recent of Bass Strait, at a depth of 15m. This occurrence extends the range back to the late Early Miocene (N8). I have also found specimens in the Late Pliocene-Pleistocene Whalers Bluff Formation at Myaring Bridge in southwest Victoria (unpublished data).

Measurements. P146996: L=0.38, H=0.26

Material. 3 specimens.

Family KRITHIDAE Mandelstam, 1960

Krithe Brady, Crosskey & Robertson, 1874

Type species. Krithe bartonensis Brady, Crosskey & Robertson, 1874

Krithe nitida Whatley & Downing, 1983

Krithe sp. McKenzie, 1974: 158, fig.3C.
Krithe nitida Whatley & Downing, 1983: 368–369, pl.4, figs7–13.
Krithe sp.C22 McKenzie & Peypouquet, 1984: 299, fig.3. — McKenzie et al. 1991: 150, pl.2, fig.14; pl.3, fig.16.
Krithe sp. Ayress, 1995: 915, figs 5.5–5.8; 13.11, 13.12.
Figured specimen. Fig.3B (P146997)

Remarks. This specimen, with its elongate posterior declivity, is not *K. postcircularis* McKenzie et al. 1993, which is characterised by a very distinctive circular posterior declivity. *Krithe swansoni* Milhau, 1993 has a more rounded anterior and different muscle scar pattern. *K.* sp. Swanson, 1979 is similar but differs from *K. nitida* mainly in its large size. *Krithe eggeri* Chapman, 1914 has a distinctive flange, which is lacking in *K. nitida*.

Although there is only one specimen in this assemblage, the significance of the genus as a palaeoecological indicator warrants detailed consideration of its occurrence. The muscle scars and Type 2 vestibule (Ayress, Barrows, Passlow & Whatley 1999: 5, fig. 2G) suggest similarities with the Late Pleistocene *K. comma* (Ayress, Barrows, Passlow & Whatley 1999: 51, figs 2G-H; 5J-M; 8U-V) which occurs in the Tasman Sea at relatively shallow depths, although *K.comma* is very large (L=1.12; H=0.48 for a male) in comparison with *K.nitida* (L=0.48; H=0.26 for the figured male specimen). *Krithe nitida's* occurrence in the Wuk Wuk Marl (N8) is within the time range established for this species by Whately & Downing (1983) and McKenzie et al. (1991) — namely Late Eocene to Middle Miocene. .

Measurements. P146997: L=0.48, H=0.26

Material. 1 specimen.

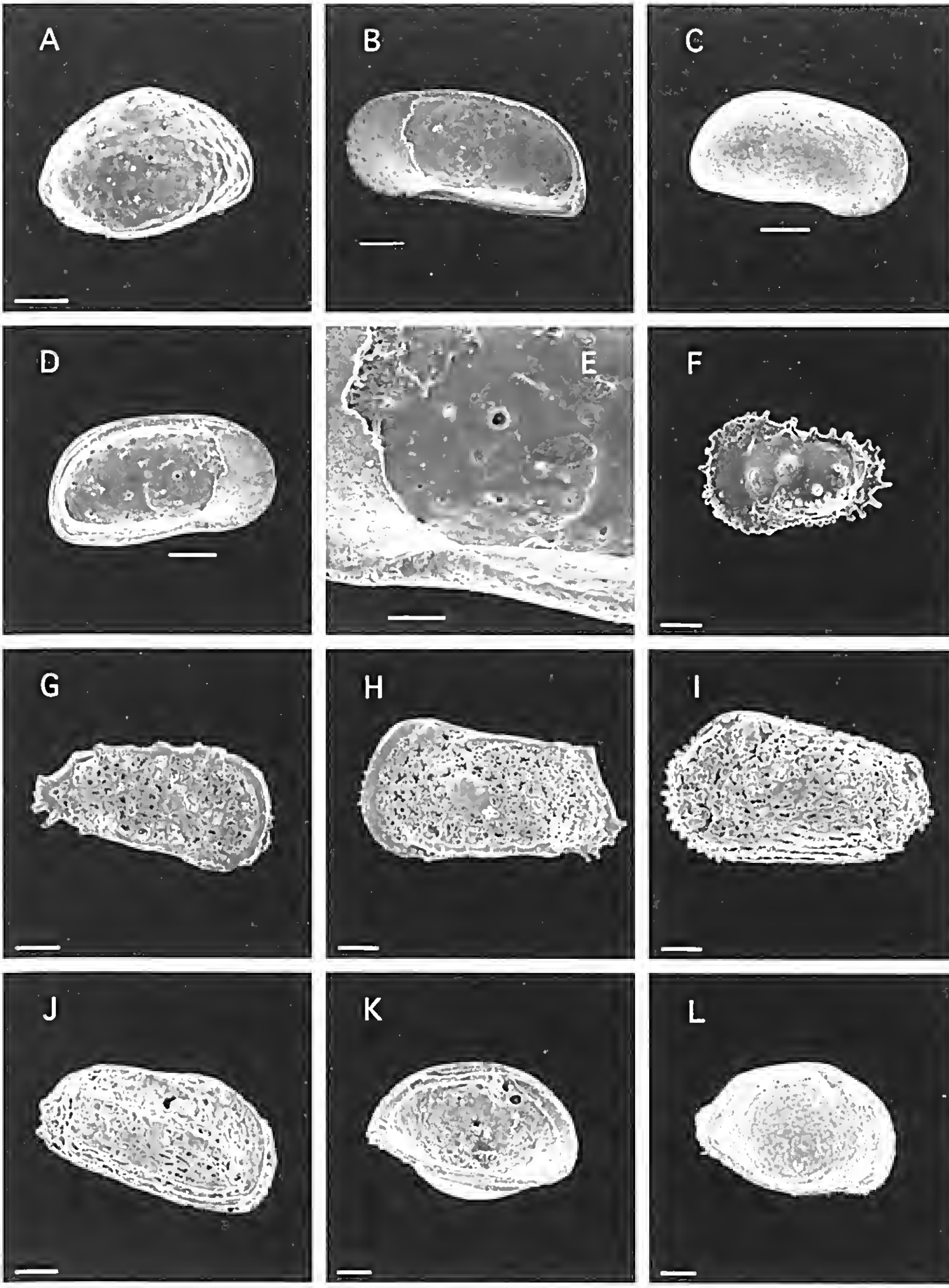

Fig. 4. A. *Rotundracythere phaseolus* 0.07mm. B. *Krithe nitida* 0.08mm. C. *Parakrithella hentyensis* 0.08mm. D. *P.hentyensis* 0.08mm. E. *P.hentyensis* 0.03mm. F. *Trachyleberis paucispinosa* G. *Cletocythereis caudispinosa* H. *C.rastromarginata* I. *Dumontina cratis* J. Gen. and sp.indet. K. *Neobuntonia batesfordense* L. *N.batesfordense*

Parakrithella Hanai, 1959

Type species. Parakrithella pseudadonta Hanai, 1959

Parakrithella hentyensis *sp.nov.*

Etymology. From the location Henty's on Grange Burn, southwestern Victoria, where this species occurs in abundance.

Types. Holotype RV (P311096). Paratypes. RV (P311096); RV (P311098) All from F31.

Figured specimens. Figs 3C-RV (P311096); D- (LV P311097); E-RV (P311098) All from F31.

Type locality. F31 Skinners, Mitchell River.

Diagnosis. A *Parakrithella* with sub-parallel dorsal and ventral margins; ventral margin slightly sinuous in LV; anteroventrally concave in RV.

Description. Valves lightly calcified and hyaline; smooth-surfaced, with a few shallow punctae on posteroventral margin. Anterior less high than posterior in RV; subequal in LV. Anterior broadly rounded with greatest lateral extension at mid-height. Anteroventral margin slightly compressed. Posterior rounded with greatest lateral extension close to ventral margin. Ventral margin slightly sinuous in LV; anteroventral concavity in RV, with characteristic extension of the anteroventral line slightly below the middle of the posteroventral border of the valve. Radial pore canals and muscle scars visible on the external surface of the valves. Rare normal pores scattered over the lateral surface — type not determinable.

Hinge structure not well preserved, but of a simple adont form, with some evidence of crenulations. Inner lamella broad anteriorly, with a broad vestibule; narrower posteriorly and ventrally, with no vestibules. Radial pore canals bifurcate at the margin; 9–10 on anterior, 5–6 on venter, 3–4 on posterior. Posteroventral angle of RV with rounded protuberance; LV margin at this point narrower and curved to receive RV, giving the sinuosity referred to above. Muscle scar pattern — dorsal adductor scar "waisted", ventromedian scar also with a distinct "waist", frontal scar u-shaped. Sexual dimorphism evident; females shorter, higher and slightly more inflated than males.

Affinities. Parakrithella hentyensis is similar in general shape and interior features to *P. australis* McKenzie, 1967, but the posteroventral angularity is more marked, and the LV sinuosity in the ventral margin is distinctive. There are no other fossil species of *Parakrithella* described or figured from southern Australia, although Warne (1987) lists one species of the Middle Miocene of the Melbourne Trough in his non-taxonomic paper, and McHenry (1996) refers to the common to abundant occurrence of two species of *Parakrithella* in the early Middle Miocene Cadell Marl and Morgan Limestone in South Australia.

Holden (1976) described two species of *Parakrithella* from the Midway area, Hawaiian Islands: *P.eopacifica* is smaller than *P.hentyensis* but the female is similar to it in lateral outline , though the male of *P.eopacifica* is much more triangular. One figure shows an invagination (Pl.17–6) in the female shell, which is not found in *Parakrithella*. *P.robusta* Holden, 1976 differs from *P.hentyensis* in its subtrapezoidal shape and larger size. *P.javana* (Kingma 1948) is similar in size to *P.hentyensis*, but has a narrower and more rounded anterior (Zhao & Whatley 1989). *P.lethiersi* Milhau (1993) is similar to *P.hentyensis* in size and lateral shape. Milhau's diagnosis refers to eight anterior marginal pore canals, of which the two dorsal are unbranched and the remaining six are often branched. This pattern is also similar to *P.hentyensis*. However, *P.hentyensis* is higher and has a more sinuous ventral margin than *P.lethiersi*.

Remarks. The limited occurrence of *P. hentyensis* in the Wuk Wuk Marl is indicative of a decrease in abundance from west to east of this genus in the Middle Miocene. The species, which is common in the Muddy Creek Marl of southwestern Victoria, was described by Neil (1992, unpublished), and is formally described here in spite of its comparative rarity.

Measurements. P311096: L=0.56, H=0.28; P311097: L=0.56, H=0.36; P311098: L=0.56, H=0.32.

Material. 5 specimens

Family TRACHYLEBERIDIDAE
Sylvester-Bradley, 1948
Subfamily TRACHYLEBERIDINAE Sylvester-Bradley, 1948
Trachyleberis Brady,1898

Type species. Cythere scabrocuneata Brady, 1880

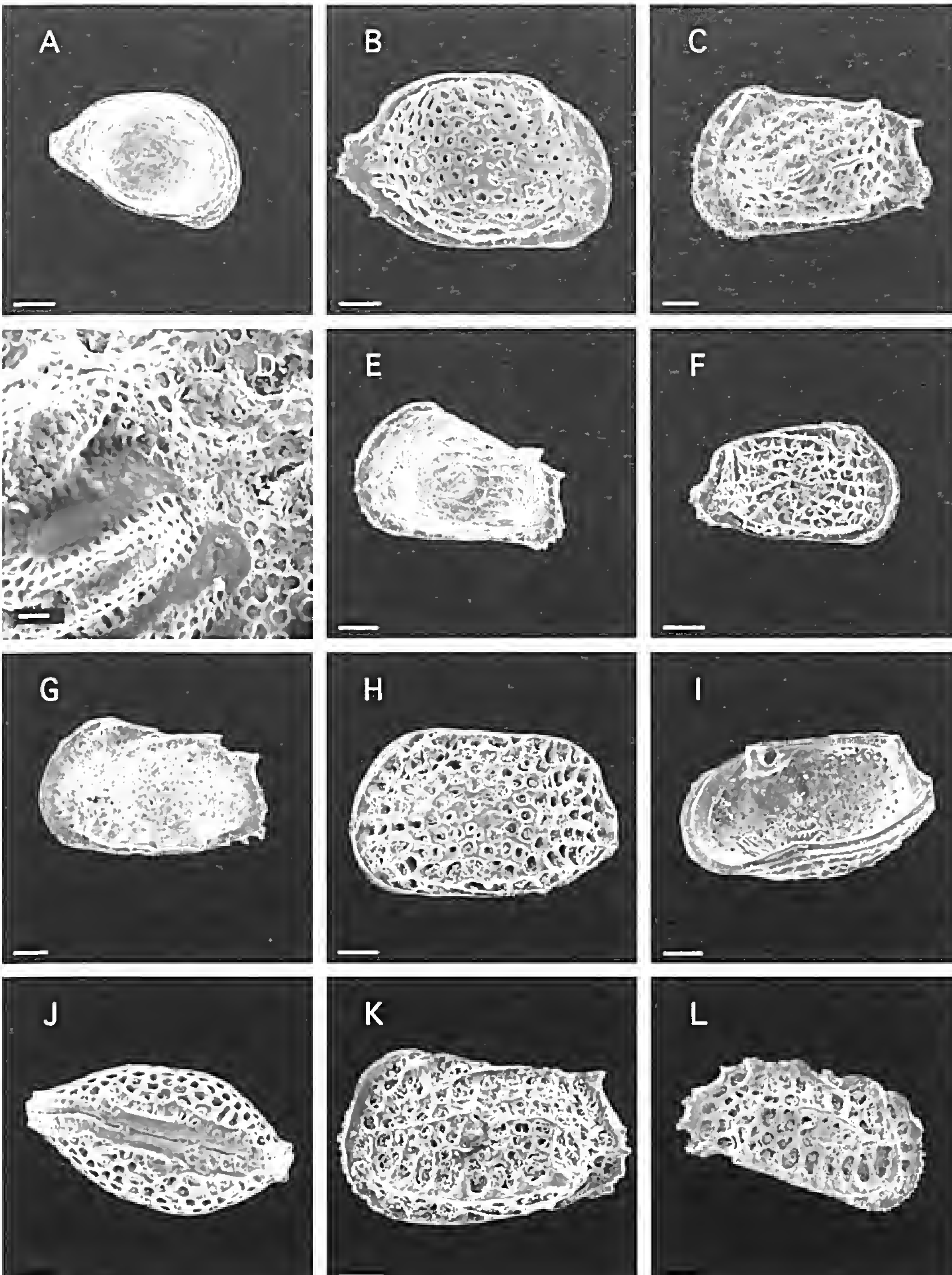

Fig. 5. A. *Neobuntonia batesfordiense* (Juvenile) B. *Pokornyella* sp. C. *Hermanites glyphica* D. *H.glyphica* 0.01mm. E. *H.glyphica* (Juvenile) F. *"Hermanites" thomasi* G. *Quadracythere* sp. H. *Quadracythere (Hornibrookelina) hentyensis* I. *Q.(H.) hentyensis* J. *Q.(H.) hentyensis* K. *Bradleya (Quasibradleya)* sp.cf.*jaujukiana* 0.09mm. L. *B.(Q.)* sp.cf.*cunazea*

Trachyleberis floridus Warne & Whatley, 1996
Trachyleberis sp.4 Warne, 1987: 442.

? Ponticocythereis sp. aff. *P. manis* Neil, 1994: 5–6, pl.2, figs 3–5.

Remarks. This single specimen, somewhat damaged, is clearly identifiable for this distinctive species, because of the characteristic scale-like spines, which are described in detail by Warne & Whatley (1996). The age is consistent with other Victorian occurrences of the species. Not figured.

Material. 1 specimen (P146998)

Trachyleberis paucispinosa ? McKenzie, Reyment & Reyment, 1993

Trachyleberis paucispinosa McKenzie, Reyment & Reyment, 1993: 105–6, pl.6, fig.8. -Ayress, 1995: fig.11.6

Figured specimen. Fig.3F (P146999)

Remarks. These two damaged specimens are questionably identifiable with the Eocene species noted by McKenzie et al. (1993) from Brown's Creek and Castle Cove and by Ayress (1995) from Waihao River, New Zealand. Consequently, the range of this species may be extended to the Miocene. The absence of any form of secondary reticulation precludes the genus **Taracythere** Ayress.

Measurements. P146999: L=0.48; H=0.32

Material. 2 juvenile specimens.

Subfamily OERTLIELLINAE Liebau, 1975
Cletocythereis Swain,1963

Type species. Cythere rastromarginata Brady, 1880

Remarks. The genus *Cletocythereis* has been discussed in detail in Malz (1980) who clarified some of the confusion surrounding Swain's erection of the genus, and by Neil (1994) in relation to the southern Australian species *C.candispinosa* and the cosmopolitan *C.rastromarginata.*

Cletocythereis caudispinosa (Chapman & Crespin, 1928)

Cythere caudispinosa Chapman & Crespin, 1928: 125, pl.9, figs 64a, b. -McKenzie, 1974: 160, pl.1, fig.4.
Oertliella sp. McKenzie, 1979: 98, pl.2, fig.1. -Whatley & Downing, 1983: 382, pl7, figs10, 11. -Warne, 1987: 442, pl.2, fig. J. -Neil, 1994: 6–7, pl.1, figs 6–9.

Figured specimen. Fig.3G (P147000)

Remarks. These specimens of *C.caudispinosa* are clearly conspecific with those examined from Muddy Creek, various Middle Miocene localities in the Leigh River area, Batesford Quarry and Western Beach, Geelong and the deeper water facies from Fossil Beach, Mornington, although preservation is variable and anterior and posterior spines are often broken. McHenry (1996) records *C. caudispinosa* from the Middle Miocene Cadell Marl in the Murray Basin. *C. taroona* McKenzie, Reyment & Reyment, 1993, from the Late Eocene Browns Creek Clays, appears to be an ancestral form of *C. caudispinosa.*

Measurements. P147000: L=0.68, H=0.34

Material. 11 specimens — 1LV, 2RV,5C and 3J.

Cletocythereis rastromarginata Brady, 1880

For synonymy see Titterton, Whatley & Whittaker, 2001, with the addition of
Bradleya rastromarginata Hornibrook, 1952: 13,17,19.
Cletocythereis sp. McKenzie, 1979: 91, pl.2, figs 4,5.

Figured specimen. Fig.3H (P147001)

Remarks. Although only a single specimen occurs in this assemblage, *C. rastromarginata* is widely distributed in Australian assemblages including the Fyansford Formation at Batesford Quarry, the Gellibrand Marl on the Leigh River, the Muddy Creek Marls near Hamilton (all Middle Miocene)and the Port Willunga Formation (Oligocene) and the Mannum Formation Middle Miocene) in South Australia. Recent forms having some similarities to

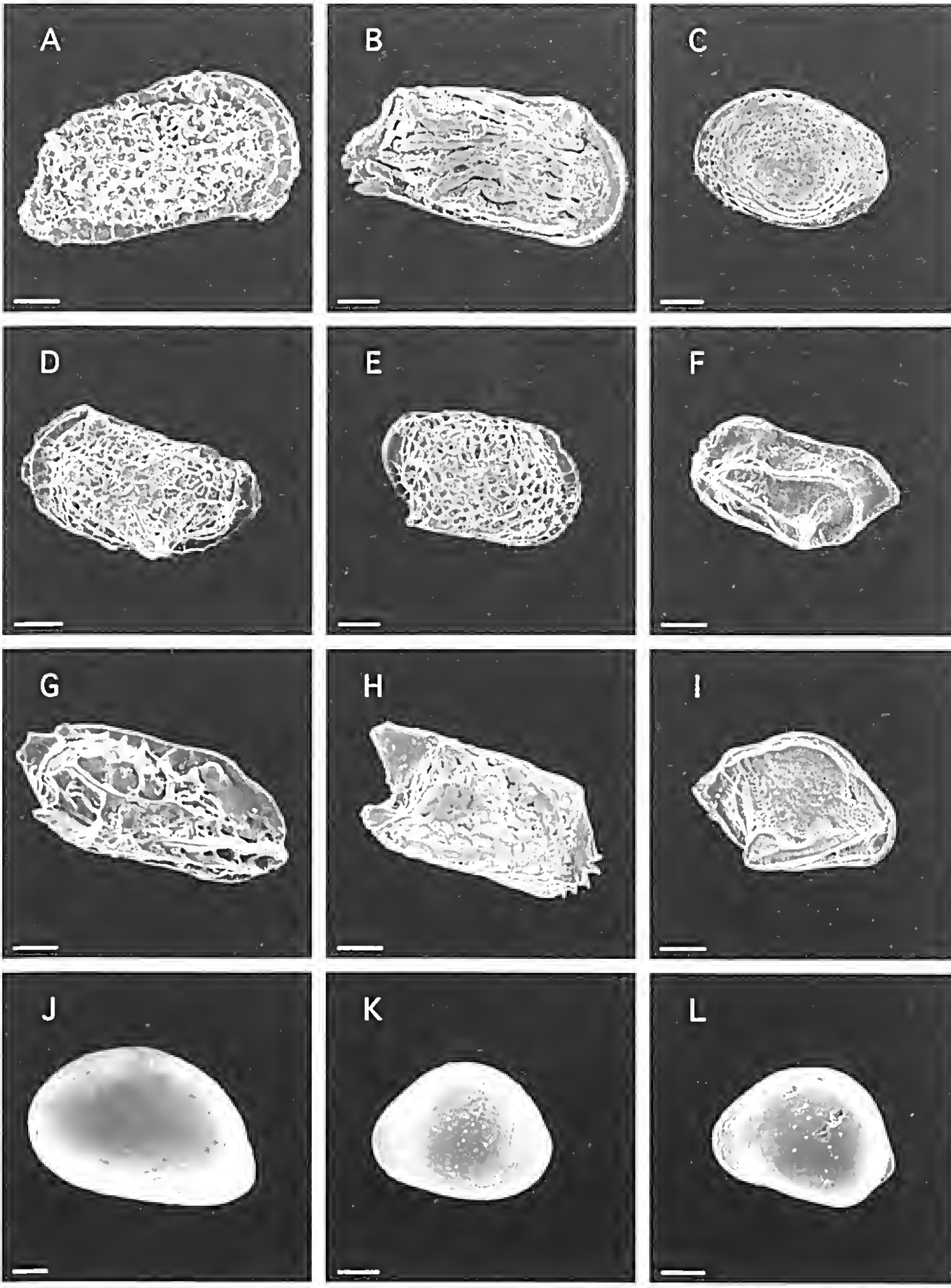

Fig. 6. A. *Spinobradleya nodosa* B. *Chapmanella flexicostata* C. *Loxoconcha propunctata* D. *L. mcgowrani* 0.09mm. E. *L.mcgowrani* F. *Semicytherura illerti* 0.05mm. G. *Semicytherura* sp. 0.05mm. H. *Eucytherura delta* 0.05mm. I. *Oculocytheropteron microfornix* 0.09mm. J. *Xestoleberis* sp. K. *Uroleberis minutissima* L. *U.minutissima*

C. watsonae Jellinek, 1993, occur commonly in beach sands at Broome, W.A. and Denham's Beach and Broken Bay in N.S.W. *Cletocythereis rastromarginata* occurs in association with *C.candispinosa* at Muddy Creek, Batesford Quarry, Leigh River and Mannum, though many other Middle Miocene localities have only *C. candispinosa*.

The development of the genus in Australasia needs further study since Hornibrook (1952) records *C.rastromarginata* from Eocene to Recent, whilst *C. taroona* and *C. candispinosa* are confined to the Eocene, Oligocene (Native Hut Creek, Leigh River, Victoria) and Miocene. Transitional forms seem to occur in some of these assemblages.

Measurements. P147001: L=0.72, H=0.38

Material. 1 specimen.

Dumontina Deroo, 1966

Type species. Cythere punctnrata Bosquet, 1854

Dumontina cratis Neil, 1994

?Dumontina cratis Neil, 1994: 8, pl.2, figs 6,7,8.

Figured specimens. Fig.31 (P147002)

Remarks. The original description of this species (Neil 1994) tentatively placed it in *Dumontina* Deroo, 1966. Further study of those specimens from Muddy Creek, and of those figured here from the Wuk Wuk Marl suggests that its placement can now be verified. An emended diagnosis and description is therefore given below.

Diagnosis. Robust *Dumontina* with strongly developed broadly-meshed reticulation and deep sulci in anterior and posterior.

Description. Valves strongly calcified and thick; dorsum and venter straight; valve tapered posteriorly in lateral view; anterior smoothly and broadly rounded; posterior rounded with slight angularity at extremity. Strong, stub-like denticulations on anteroventral and posteroventral margins. Thick marginal anterior and posterior ribs, obscured by flat-surfaced nodules. Reticulation of flat-surfaced ribs bordering deep, relatively small fossae which have a longitudinal trend in ventral half, and irregularly distributed on remainder. Subcentral tubercle marked by few or no fossae, scarcely protruding above valve surface. U-shaped frontal scar sometimes visible on exterior. Prominent, clear eye tubercle at antero-dorsal angle.

Hinge strongly holamphidont; anterior tooth in RV curved; median elements smooth in both valves. Anterior lamella of moderate width in anterior and posterior, narrower ventrally. No vestibules. Radial pore canals numerous (15–20 anterior; 10–12 posterior), unbranched, occasionally paired or grouped, generally single. Muscle scar pattern with u-shaped frontal scar, and 4 elongated adductors, dorsal adductor clearly divided into two. Sexual dimorphism — males longer and less high than females.

Affinities. There are no other *Dumontina* species described or figured from Australasia. Warne (1987) lists one species from the Port Phillip Basin. The occurrence of *?D. cratis* in Palaeocene sediments (Neil 1997) must be regarded as questionable. *Dumontina cratis* occurs in the assemblages compiled by the writer from Batesford Quarry (Fyansford Formation), Leigh River (Gellibrand Marl), Fishing Point (Fishing Point Marl) and Kingston-on-the-Murray, South Australia (Mannum Formation). The European species figured by Deroo (1966) differs in having finer-meshed reticulation, and lacking the anterior and posterior sulci with nodes. Few species have been referred to this genus.

Measurements. P147002: L=0.76, H=0.42

Material. 22 specimens (10 carapaces, 11 valves, 1 internal mould).

Actinocythereis Puri, 1953

Type species. Cythere exanthemata Ulrich & Bassler, 1904

?Actinocythereis sp.

Actinocythereis sp.A Neil, 1994: 5, pl.1, figs 4,5.

Remarks. Three specimens are here tentatively referred to *Actinocythereis* Puri, 1953 for reasons set out in Neil (1994: 5). Two of the specimens are very degraded, so that even conspecificity with the more abundant material from Muddy Creek is doubtful. Not figured.

Material. 3 specimens, 1 adult, 2 juvenile (P147003)

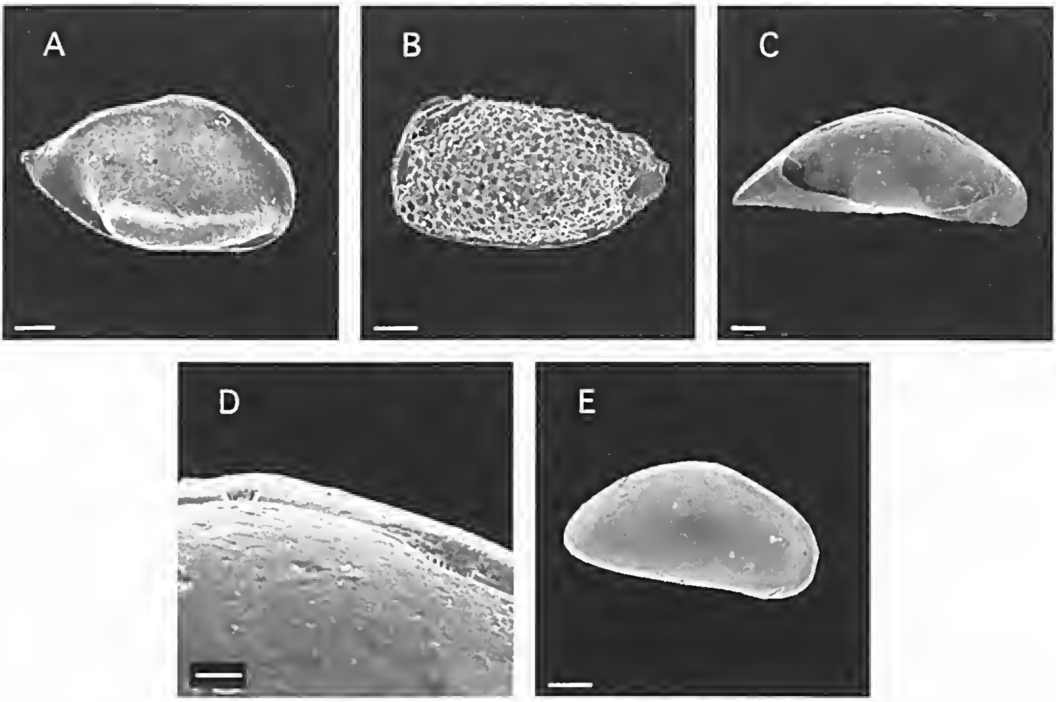

Fig. 7. A. *Bythoceratina* sp. B. *Hanaiceratina balcombensis* C. *Macrocypris* sp.1 D. *Macrocypris* sp.1 0.03mm. E. *Macrocypris* sp.2

Tribe AUSTRALIMOOSELINI Hartmann, 1978

Remarks. Although the higher category of tribe is not utilised elsewhere in this taxonomic account, the placement of the specimen described below presents difficulties already recognised by Howe & McKenzie (1989) in their discussion of the genera *Australimoosella, Mackencythere, Doratocythere* and *Yassinicythere.* The specimen has sufficient characters of the campylocytherine trachyleberidids to be placed in this tribe — general shape, reticulation style, median ridge, muscle platform and muscle scar pattern. However, the posterior shows a slight, denticulate cauda which is not present in any of the named genera. Furthermore, the specimen is degraded by dissolution of the valve material. It is less attenuated in length than figured *Mackencythere* species; its reticulation is not ribbed like most *Australimoosella; Yassinicythere* has more evenly rounded anterior and posterior margins.

Gen. and sp. indet.

Figured specimen. Fig.3J (P147004)

Remarks. A campylocytherine trachyleberidid species with broad, flat-surfaced reticulation, aligned longitudinally in ventral half; narrow median rib; anterior flange and sulcus; slightly caudate posterior with denticulations. Unlike other Australian species in this group (Tribe Australimoosellini Hartmann, 1978) which are confined to the Pleistocene and Recent, this specimen extends the range of the tribe to the Middle Miocene.

Measurements. P147004: L=0.84, H=0.46

Material. 1 specimen.

Family HEMICYTHERIDAE Puri, 1953
Neobuntonia Hartmann, 1981

Type species. Neobuntonia siebertorum Hartmann, 1981

Remarks. The diagnosis for the genus *Neobuntonia* Hartmann, 1981 was emended to include muscle scars (Neil 1994) and so confirm its place in the Hemicytheridae with this additional diagnostic character. McKenzie et al. (1991) discussed the generic

placement of *Neobuntonia* , which they retained in the Hemicytheridae in spite of external valve similarities to the trachyleberidine *Incongruellina* Ruggieri, 1958 and *Carinovalva* Sissingh, 1973. These similarities (a marked ventral keel, and a subtrapezoidal lateral outline) would suggest that both *Neobuntonia airella* McKenzie et al. 1991 and *Neobuntonia oneroaensis* Milhau, 1993 from the Early Miocene of New Zealand are better placed in the genus *Notocarinovalva* Neil, 1994. Variations in the punctation of *Neobuntonia* and *Notocarinovalva* are discussed in Neil (2000a: 172–173).

Neobuntonia batesfordiense (Chapman, 1910)

Cytheropteron batesfordiense Chapman, 1910: 300–301, pl.2, figs 7a-c. — Chapman, 1914: 45, pl.8, fig.36.
Neobuntonia batesfordiense Neil, 1994: 27, pl.6, figs 2,3,4; pl.14, fig.5. — McHenry, 1996: pl.6, fig.J.

Figured specimens. Fig.3K (P311059); 3L (P311060); Fig.4A (P311061) Juvenile.

Remarks. Neobuntonia batesfordiense is one of the most common species in this assemblage and is clearly conspecific with specimens from the type locality, Batesford Quarry. The Wuk Wuk Marl specimens are usually heavily calcified, even in juveniles. *Neobuntonia batesfordiense* occurs widely in southern Australia from the Lower Morgan Limestone at Kingston-on-Murray and Blanchetown in South Australia, from Muddy Creek, Point Addis, Zeally Bay and Fishing Point in western and central coastal Victoria, and from Fossil Bluff in northern Tasmania (Neil, unpublished data). The closely related species *Notocarinovalva yulecartensis* Neil, 1994 (see above in remarks for the genus *Neobuntonia*) also occurs widely in the same general area, but not in the Wuk Wuk Marl nor in any assemblage containing *N. batesfordiense*, suggesting that the two species occupy a similar ecological niche.

Stratigraphically, *N. batesfordiense* is common in the late Early Miocene (Batesfordian). It ranges from the Early Miocene (Longfordian) at Point Addis and Fossil Bluff to the youngest occurrence in this Middle Miocene (Balcombian) assemblage at Skinners.

Measurements. P311059: L=0.84, H=0.54; P311060: L=0.84, H=0.52; P311061: L=0.44, H=0.34

Material. 59 specimens (35 RV, 18 LV, 6 C).

Subfamily HEMICYTHERINAE Puri, 1953

Pokornyella Oertli, 1956

Type species. Cythere limbata Bosquet, 1852

Pokornyella sp.

Pokornyella sp.1 Warne, 1987: 438, pl.3, fig.E

Figured specimens. Fig.4B (P311062)

Remarks. Pokornyella species occur rarely in Australian assemblages, but their occurrence nonetheless indicates the presence of a significant cosmopolitan genus (McKenzie 1967, 1974). *Pokornyella* sp. from the Wuk Wuk Marl is a punctate, rather than reticulate form, with a distinct, slightly denticulate cauda, and marked anterior and posterior flanges without ridges or punctae. The juvenile form is more quadrate in lateral view. It also occurs in the late Early to early Middle Miocene Fyansford Marl in the Port Phillip Basin (Warne 1987). It differs from *Cytherura praemucronata* Chapman & Crespin (1928) from the Late Oligocene of the Sorrento Bore in its more prominent anterior flange and its smaller size. Chapman & Crespin's species was later assigned to *Pokornyella* s.l. by McKenzie (1981). Other Australian *Pokornyella* species differ. *Pokornyella australiae* McKenzie, Reyment & Reyment, 1991: pl.7, fig.4, pl.10, figs 5–8 from the Late Oligocene of Bells Headland has a longitudinally ribbed reticulation and no flanges. *Pokornyella* s.l. sp. McKenzie, 1979 is rounded and non-caudate. *Pokornyella* s.l. sp. McKenzie, 1974 is very small, longitudinally ribbed and has a recurved venter. A single specimen from the Fishing Point Marl may be conspecific with the Wuk Wuk Marl species, but the anterior ridge is narrower, and the punctae are larger with correspondingly smaller interareas.

Measurements. P311062: L=0.76, H=0.48

Material. 3 specimens, 1 RV, 1 LV, 1 juvenile LV.

Subfamily THAEROCYTHERINAE Hazel. 1967

Hermanites Puri, 1955

Type species. Hermanites reticulata Puri, 1953

Hermanites glyphica Neil, 1994

Hermanites glyphica Neil, 1994:17, pl.7, figs 3–8, pl.12,fig.4. — McHenry, 1996: pl.8, fig.A.

Figured specimens. Figs 4C, D (P311063); 4E (P311064)

Remarks. This hemicytherid species is characteristic of a number of southeast Australian assemblages. It occurs generally as a common element in shallow-water assemblages in marl-type facies. Stratigraphically it ranges from the Late Oligocene/Early Miocene Point Addis Limestone to the Late Miocene marl at Western Beach Geelong, so that it is a good mid-Tertiary marker. Palaeogeographically it occurs from the Morgan Limestone at Kingston-on-Murray, South Australia in the west to the Wuk Wuk Marl in Gippsland, Victoria in the east. I have found it also in assemblages from Muddy Creek, southwest Victoria, Batesford Quarry, the Gippsland Oil Shaft core and at Fossil Bluff in northern Tasmania. McHenry (1996) has found it in the Lower Morgan Limestone, between Morgan and Blanchetown, South Australia.

Its strongly reticulate "ornamentation", and the striking differences in reticulation style between adults and juveniles (Neil 2000) make it a distinctive element in all these Tertiary assemblages. Subtle differences in macro- and micro-reticulation patterns are the subject of continuing investigation (Neil 2002) and may eventually provide evolutionary or palaeoenvironmental cues.

Measurements. P311063: L=1.00, H=0.64; P311064: L=0.58, H=0.34

Material. 30 specimens, adult and juvenile.

'Hermanites' lungulata (McKenzie, Reyment & Reyment, 1991)

Bradleya lungulata McKenzie, Reyment & Reyment, 1991: 162, pl.6, fig.8, pl.10, figs 9,10.
'Bradleya' lungulata McKenzie, Reyment & Reyment, 1993: 113, pl.7, fig.13, pl.8, fig.19.
'Hermanites' lungulata Neil, 1994: 18–19, pl.6, figs 9–10, pl.7, figs 1–2, pl.14, fig.7

Remarks. This species is a common element in a number of Miocene assemblages across southeastern Australia. Its generic assignment has been discussed by McKenzie et al. (1991,1993) and Neil (1994) but remains unresolved. The affinities of *'H'. lungulata* have been discussed in relation to specimens from Muddy Creek (Neil 1994). The stratigraphic range of *'H'. lungulata* is not extended by the occurrences noted by the writer from Batesford Quarry, Fishing Point, Western Beach Geelong and Port Willunga, though the last of these is the only occurrence in South Australia. Not figured (P311065)

Material. 23 specimens.

'Hermanites' thomasi Neil, 1994

?Grinioneis sp.1 Warne, 1987: 443, pl.3, fig.1.
'Hermanites' thomasi Neil, 1994: 17–18, pl.7, figs 9,10; pl.8, figs 1,2; pl.10, fig.9; pl.12, figs7,8; pl.14, 14, fig.6.

Figured specimen. Fig.4F (P311066)

Remarks. 'Hermanites' thomasi in southeastern Australia displays a level of intraspecific variation (Neil 2000a), though specimens In this assemblage are generally uniform in their reticulation pattern. The difficulty of the muscle scar pattern resembling that of auriline genera such as *Mutilus* and *Aurila* (Neil 1992) is not resolved by this population, since there are 3 sub-circular frontal scars, unlike the 2 scars diagnostic of *Hermanites sensu stricto.* Assignment to *Hermanites* remains tentative.

'Hermanites' thomasi occurs from southwestern Victoria to Skinners in Gippsland and ranges from early Middle Miocene to early Late Miocene. It is common to abundant in assemblages from Bahgallah and Myaring Bridge, Muddy Creek, Fishing Point, Warrambine and Native Hut Creeks, Farrells, Batesford Quarry and Western Beach Geelong, as well as in the Wuk Wuk Marl at Skinners.

Measurements. P311066: L=0.60, H=0.34

Material. 16 specimens.

Subfamily BRADLEYINAE
Benson, 1972

Quadracythere Hornibrook, 1952

Type species. Cythere truncula Brady, 1898

Subgenus **Quadracythere** Hornibrook, 1952

Remarks. Because of the complexity of the taxonomy of this genus, the use of the recognised subgenera is essential.

Quadracythere (Quadracythere) sp.aff. **Quadracythere spica** Holden, 1976

Quadracythere (Quadracythere) spica Holden, 1976: F24, pl.5, figs 22,25.
Quadracythre aldingaensis Majoran, 1996: 259, 261, fig.8, J-L.
Quadracythere sp.2 McHenry, 1996: pl.7, fig.E.

Remarks. Although *Quadracythere (Q.)* sp.aff. *Q.(Q.) spica* is the most abundant element in a collection of nearly 10 000 specimens from Muddy Creek and Grange Burn in southwestern Victoria, Skinner's assemblage produced only 19 specimens. They lack the distinctive posteriorly directed posterodorsal spine of *Q.(Q.) spica s.s.*, but in other respects are similar. Other New Zealand and Recent Australian *Quadracythere (Quadracythere)* species all differ in size, shape or rib pattern from *Q.(Q). spica.* McKenzie, Reyment & Reyment's (1991) species *Q.singletoni* is also quite distinct in its lateral outline and reticulation. Not figured (P311067)

Material. 19 specimens.

Quadracythere (Quadracythere) sp.

Figured specimen. Fig.4G (P311068)

Remarks. These specimens are of characteristic *Quadracythere* lateral shape, but differ from other Australian species in having an apparently punctate rather than reticulate surface. With the limited number of specimens it is not possible to determine whether an original ribbed reticulation has been overlaid or eclated, leaving only small, irregular fossae, or a more or less uniform surface shows punctae. The presence of a flat anterior flange bordered by 8 or 9 fossae may indicate the first alternative to be more likely. The species does not occur in any other southeast Australian fossil assemblage.

Measurements. P311068: L=0.96, H=0.52

Material. 3 specimens.

Subgenus **Hornibrookellina** Neil, 1994

Quadracythere (Hornibrookellina) hentyensis Neil, 1994

Quadracythere (Hornibrookellina) hentyensis Neil, 1994: 23–25, pl.9, figs 7,8,10,; pl.10, fig.1; pl.13, fig.4; pl.14, fig.9.

Figured specimens. Figs 4H (P311069); 4I (P311070), 4J (P311071)

Remarks. These specimens are conspecific with the population from Muddy Creek at Henty's. Small numbers also occur in assemblages from Fishing Point, Native Hut Creek, Bells Headland, Western Beach Geelong and Fossil Bluff, Tasmania.

Measurements. P311069: L=0.74, H=0.42; P311070: L=0.78, H=0.42; P311071: L=0.84, W=0.42

Material. 22 specimens.

Bradleya Hornibrook, 1952

Type species. Cythere arata Brady, 1880

Subgenus **Bradleya** Benson, 1972

Bradleya (Bradleya) kincaidiana (Chapman, 1926)

Bradleya (Bradleya) sp.cf. *kincaidiana* Neil, 1994: 21, pl.8, figs 8–10.

Remarks. See discussion of this species in Neil (1994: 21). Some of these specimens show the posterodorsal spine of Chapman's species, but variations in the size of the spine are regarded as intraspecific. Not figured (P311072)

Material. 19 specimens.

Subgenus **Quasibradleya** Benson, 1972

(Bradleya)Quasibradleya sp.cf. **Quasibradleya janjukiana** McKenzie , Reyment & Reyment, 991

Quasibradleya janjukiana McKenzie, Reyment & Reyment, 1991: 166, pl.6, figs14–16, pl.8, fig.2.

Quasibradleya cf. *momitea* Majoran, 1996: pl.1, fig.12.

Figured specimen. Fig.4K (P311073)

Remarks. This specimen is close to *B.(Quasibradleya.) janjukiana* in its straight dorsum and reticulation pattern. Majoran's species (*Q.* cf.*momitea*) is also closer to *B.(Q.) janjukiana* than to *Q. momitea* McKenzie et al. 1993.

Measurements. P311073: L=0.66, H=0.36

Material. 1 specimen.

Bradleya (Quasibradleya) sp.cf. **Quasibradleya cunazea** (Hornibrook, 1952)

Bradleya cunazea Hornibrook, 1952: 41, pl.6, figs 87–89.
Quasibradleya cunazea Ayress, 1993a: fig.9N.

Figured specimen. Fig.4L (P311074)

Remarks. These specimens are more carinate than the ones figured by Ayress (1993) and Hornibrook (1952), and have a straight dorsal margin, but are regarded as having affinities with them. They are less box-like than *B.(Q.) pyxos* Neil, 1994. They differ from *Q. janjukiana* McKenzie, Reyment & Reyment, 1991 and *Q. momitea* McKenzie, Reyment & Reyment, 1993 in their strong cauda, central reticulation pattern and unbroken median rib. *Q. elongata* Howe & McKenzie, 1989 has rounded, rather than carinate ribs. The species does not occur in other southeast Australian assemblages.

Measurements. P311074: L=1.00, H=0.52

Material. 3 specimens.

Spinobradleya McKenzie et al. 1991

Type species. Spinobradleya acantha McKenzie et al. 1991

Spinobradleya nodosa Neil, 1994

Spinobradleya nodosa Neil, 1994: 19–20, pl.8, figs 3,4,5,6. — McHenry, 1996: pl.7J

Figured specimen. Fig.5A (P311075)

Remarks. A single specimen represents this species which is, however, common to abundant at Muddy Creek, Native Hut Creek, Western Beach Geelong and Fossil Beach, Mornington.

Measurements. P311075: L=0.76, H=0.42

Material. 1 specimen.

Subfamily UROCYTHEREIDINAE
Hartmann & Puri, 1974

Chapmanella Neil, 1994

Type species. Cythere flexicostata Chapman, 1914

Chapmanella flexicostata (Chapman, 1914)

Cythere flexicostata Chapman, 1914: 35–36, pl.7, figs 14a,14b. — McKenzie, 1974: 160.
(?Bradleyini) gen.C *flexicostata* Warne, 1987: 443.
Hornibrookella flexicostata McKenzie, Reyment & Reyment, 1991:159–160, pl.10, fig.11.
Chapmanella flexicostata Neil, 1994: 25–27, pl.10, figs 2–8, pl.13, figs 5,6. — McHenry, 1996: pl.7, fig.I. — Neil, 2000a:pl.2, figs 6,7,8, pl.3, figs 1–6, pl.6, figs 5–7.

Figured specimen. Fig.5B (P311076)

Remarks. Because of intraspecific variation in this species (Neil 2000), some characteristics of the figured specimen, particularly the celated ribs, may not be shared by other specimens in the assemblage. However, the broad, flat-surfaced ribs figured (Fig. 5B) occur in all the populations studied by the writer, as well as narrow-ribbed and rounded-ribbed specimens. Even the pattern of the ribbed reticulation shows some variations, though the species remains quite distinctive and easily identified. *Chapmanella flexicostata* is a significant component of this assemblage, with 21 specimens.

Measurements. P311076: L=0.76,H=0.40

Material. 21 specimens (12 C, 5 RV, 4L).

Family LOXOCONCHIDAE Sars, 1925

Loxoconcha Sars, 1866

Type species. Cythere rhomboidea Fischer, 1855

Loxoconcha propunctata Hornibrook, 1852

Loxoconcha propunctata Hornibrook, 1952: 49, pl.11, figs 148,149,153.
L.ruwarungensis Majoran, 1996: 262, 264, figs 9A-D.

Figured specimen. Fig.5C (P311077)

Remarks. Although loxoconchids are common in many southern Australian Miocene assemblages, this New Zealand species has been recorded only by Majoran (1996) (as *L.ruwarungensis)* and in the Skinner's assemblage in Australia. However, I have also found a population of *L.propunctata* showing a range of variation in punctation, in the late Pliocene/ Pleistocene (Werrikooian) Crawford Member of the Whalers Bluff Formation at Myaring Bridge, southwest Victoria. The absence of punctation or reticulation on much of the lateral surface of the Skinner's specimens might suggest aggradation of characteristically more punctate/reticulate forms, but Majoran's *L.ruwarungensis* (1996), which I have placed in synonymy with *L.propunctata,* has a similar pattern which he discusses (1996: 264). Intraspecific variation of punctation/reticulation in loxoconchids has also been discussed by Neil (2000). Swanson (1969) figures *L.propunctata* with a fully punctate surface. As a consequence, *L.propunctata* and *L.ruwarungensis* and these specimens are all regarded as having affinities at the species level.

Measurements. P311077: L=0.54, H=0.38

Material. 23 specimens.

Loxoconcha mcgowrani McKenzie et al. 1991

Loxoconcha sp.2 Warne, 1987: pl.4, fig.D.
Loxoconcha mcgowrani McKenzie et al. 1991: 151, pl.5, figs 7,8a,8b, pl.8, figs 1a, 1b.
Loxoconcha cf. *mcgowrani* McHenry, 1996: Pl.8, fig.1.

Figured specimens. Fig.5D Male LV (P311078); Fig.5E Female RV (P311079)

Remarks. This occurrence extends the range of *L. mcgowrani* from the Late Oligocene to early Middle Miocene, as was suggested by McKenzie et al. (1991). This small population is clearly conspecific with the specimens from western Victoria coastal locations (McKenzie et al. 1991). It differs from most Recent species figured by Hartmann (1978, 1979, 1981) and Howe & McKenzie (1989) in the subrhomboidal shape of its members. Although this shape is somewhat similar to that of *L. trita* McKenzie, 1967, its narrow-ribbed reticulation and posterodorsal flange distinguish it from that Recent species with its posterior flange. Although McKenzie, Reyment and Reyment (1991:151) state that sexual dimorphism is not confirmed by their material, they figure a male and a female which are clearly differentiated. The specimens illustrated here (Figs 6D, E) match their male and female figures (McKenzie, Reyment & Reyment 1991: Pl.5, figs 7, 8a, b). Another species with a marked posterodorsal flange occurs in the early Middle Miocene Muddy Creek Marl of southwest Victoria. It has been suggested (Ayress: pers.comm. 2004) that *L.mcgowrani* is a *Sagmatocythere* species. However, the secondary reticulation noted by Milhau (1993) and figured by Ayress (1995: Fig.8 –3/8-8)for New Zealnd species is missing from *L.mcgowrani.*

Measurements. P311078: L=0.50, H=0.30 ; P311079: L=0.54, H=0.32

Material. 9 specimens.

Family CYTHERURIDAE G.W.Müller, 1894
Semicytherura Wagner, 1957

Type species. Cythere nigrescens Baird, 1838.

Semicytherura illerti Yassini, 1987

Semicytherura illerti Yassini *in* Yassini & Wright, 1987: 172, figs J-N. — Yassini & Jones, 1995: 369, figs 471,473,475,479,481,483.

Figured specimen. Fig.5F (P311080)

Remarks. A single specimen which is the first fossil occurrence of this Recent species of Australian tropical and warm temperate waters, extending its range back to the early Middle Miocene. *Semicytherura cretae* Neale, 1975 from Gingin in Western Australia may well be an ancestral form of this species.

Measurements. P311080: L=0.28, H=0.16

Material. 1 specimen.

Semicytherura sp.

Figured specimen. Fig.5G (P311081)

Remarks. This single specimen shows some similarities to *S. cryptifera* (Brady 1880) though the reticulation pattern differs from the figures given by McKenzie (1967), Hartmann (1979), Yassini, Jones & Jones (1993) and Yassini & Jones (1995). Warne (1987) listed five species of *Semicytherura* from his Middle Miocene samples of the Melbourne Trough, but none was figured or described. McHenry (1996: pl.6, fig.B) illustrates a *Semicytherura* sp.2 from the Lower Morgan Limestone which is conspecific with *Semicytherura* sp. figured here. Variation in reticulation pattern in *Semicytherura* species is often a criterion for diagnosing new species, so that it is not possible to assign this specimen to any described species.

Measurements. P311081: L=0.40, H=0.18

Material. 1 specimen.

Eucytherura G.W.Müller, 1894

Type species. Cythere complexa Brady, 1866

Eucytherura delta McKenzie, Reyment & Reyment, 1993

Eucytherura sp.1 Whatley & Downing, 1983: 272, pl.5, figs 10.11.
Eucytherura delta McKenzie, Reyment & Reyment, 1993:100,pl.5, figs 1,2.

Figured specimen. Fig.5H (P311082)

Remarks. A single specimen of *E.delta* extends its stratigraphic range from the Late Eocene to the Middle Miocene. *Eucytherura* sp.1 Whatley & Downing, 1983, is placed in synonymy because the anterior teeth (4 in McKenzie et al. description; 5 in Whatley & Downing, though not visible in their figure, and here) and the characteristic elongate pitting are clearly present. This species is quite distinct in its caudate shape and pitting from other Australian species of *Eucytherura.*

Measurements. P311082: L=0.32, H=0.18

Material. 1 specimen.

Oculocytheropteron Bate, 1972

Type species. Oculocytheropteron praenuntatum Bate, 1972: 50, pl.16, figs 1–12, pl.19, figs 2,3, text-figs 28a–c.

Oculocytheropteron microfornix Whatley & Downing, 1983

? Cytheropteron praeantarcticum Chapman 1914: 47, pl.9, figs 39a,b.
Oculocytheropteron sp. McKenzie, 1974: 162, pl.3, fig.1.
Oculocytheropteron microfornix Whatley & Downing, 1983: 372–373, pl.5, figs 3–9. — Ayress, 1996: 3–319, pl.2, fig.16. — McHenry, 1996: pl.6, fig.A. — Majoran, 1997: 431, fig.6.18–19.
Oculocytheropteron cf.*microfornix* McKenzie, Reyment & Reyment, 1991: 156, pl.6, fig.2, pl.7, fig.3.
"Oculocytheropteron" microfornix Neil, 1992: 186, pl.16, fig. E.

Figured specimen . Fig.5I (P311083)

Remarks. These specimens show some of the variability in "ribbing and pitting" referred to by Whatley & Downing (1983), but are clearly conspecific. The specimen figured by McKenzie (1974: pl.3, fig.1) from Rutledge Creek, near Loch Ard Gorge, belongs to this species. In view of the stated variability in this species, McKenzie et al.'s tentative placement of their specimens from Bells Headland and Blanche Point, South Australia is unnecessary and so the stratigraphic range of the species extends from Late Eocene or Early Oligocene to early Middle Miocene. Over 600 specimens from Muddy Creek in southwestern Victoria (Neil 1992) underline the widespread occurrence of this species in Middle Tertiary assemblages.

The earliest description of a species resembling *Oculocytheropteron microfornix* is that of *Cytheropteron praeantarcticum* by Chapman (1914: 47, pl.9, figs 39a,b). The single specimen described by Chapman (1914) is a left valve, possibly male. Dr Mark Warne, who is currently studying Chapman's types from the Mallee Bores paper (Chapman 1914), has provided me with SEM images of this specimen. Although *Oculocytheropteron praeantacticum* (Chapman,1914) shares some characteristics of shape, alar and caudal development and surface ornamentation

with *O.microfornix* Whatley & Downing, 1983, a decision on conspecificity is more appropriately left with Dr Warne. McKenzie (1982) re-examined the types and listed *C.praeantarcticum* as *Oculocytheropteron*, but did not give a specific name (Whatley & Downing's description was published in 1983).

Specimens of *O.microfornix* also occur in assemblages at Jemmy's Point Gippsland (Pliocene); Myaring Bridge (Plio-Pleistocene) and Batesford Quarry, Fishing Point and Western Beach Geelong (Miocene).

Measurements. P311083: L=0.42, H=0.30

Material. 9 specimens.

Kangarina Coryell & Fields, 1937

Type species. Kangarina quellita Coryell & Fields, 1937: 13, fig.15a-c.

Kangarina sp.1

Remarks. This specimen is related to the lineage illustrated by McKenzie (*Kangarina* sp. — 1974: pl.8, fig.8). It differs from *Kangarina macropus* Whatley & Downing, 1983, which is a member of that lineage, in its size, rib pattern and micro-ornament. Similarly it differs from other southern Australian *Kangarina* species in these characteristics. Not figured (P311084)

Material. 1 specimen.

Kangarina sp.2

Remarks. This slightly punctate specimen with ill-defined ribs shows some similarities in its shape and dorsal flange to *K.wareelacogarra* McKenzie, Reyment & Reyment, 1993, which has been noted from South Australia and Victoria. Not figured (P311085)

Material. 1 specimen.

Family XESTOLEBERIDIDAE Sars, 1928

Xestoleberis Sars, 1866

Type species. Cythere aurantia Baird, 1838: 143, pl.5, fig.26

Xestoleberis sp.

Figured specimen. Fig.5J (P311086)

Remarks. The distinguishing characteristic of these specimens, apart from their large size and inflation, is the surface marking of the normal pores by distinct pits, giving a "spotted" appearance to the valves. No other described and figured *Xestoleberis* species from Australia shows this feature. However, Swanson (1979: 34, fig.54) in describing a *Xestoleberis* sp. from the Otago Shelf, New Zealand, refers to normal pores which appear externally as surface pitting. The present specimens are similar in shape and structure to Swanson's, but the pitting is less dense, and the valves are larger. With only three specimens, it is felt a new species cannot be erected.

Measurements. The height range is from 0.42 mm. to 0.44 mm., and the length from 0.58 mm. to 0.60 mm. P311086: L=0.92, H=0.60

Material. 3 specimens.

Uroleberis Triebel, 1958

Type species. Eocytheropteronparnensis Apostolescu, 1955: 259, p.4, figs 66–67.

Uroleberis minutissima (Chapman, 1926)

Bairdia minutissima Chapman, 1926: 132. pl.10, figs 2a,b.
Uroleberis sp. Triebel, 1958: 110, pl.3, figs 14a,b.
Uroleberis minutissima McKenzie, 1974: 163, pl.1, fig.14. — Whatley & Downing, 1983: 384, pl.7, fig.20. — Warne, 1987: 444. — Ayress, 1995: 901 (Table 1), figs 12.4–12.6.
Foveoleberis sp. McKenzie, Reyment & Reyment, 1990: 17, pl.5, fig.4, pl.8, fig.7.
Foveoleberis minutissima McKenzie, Reyment & Reyment, 1991: 154, pl.5, fig.12.
Uroleberis sp. cf.*minutissima* Neil, 1992: 194–195, pl.17, fig.11.
Foveoleberis minutissima sublaevis McKenzie, Reyment & Reyment, 1993: 89, pl.3, fig.9.

Figured specimens. Figs 5K (P311087); 5L (P311088)

Remarks. These specimens show a range of variability in the foveolation of the valves (Figs 5K, L). Mc-

Kenzie (1974) and McKenzie et al. (1990, 1991, 1993) have commented on this variability . Although they have used the foveolation as a diagnostic character for a subspecies, I believe such variations are intra specific within populations as is the case here (36 specimens) and at Muddy Creek (317 specimens).

Some of the confusion between *Uroleberis* and *Foveoleberis* would have been avoided had Malz (1980) used the term "Grube" which means "pit, fossa, fovea", rather than the term "Grübchen" which clearly means "small pit, little hole, fossula" (DeVries 1959), since the type species *Foveoleberis foveolata* (Brady 1880) is clearly punctate.

Uroleberis minutissima has been the subject of an investigative paper by Neale & Singh (1988).

Measurements. P311087: L=0.48, H=0.36; P311088: L=0.46, H=0.36

Material. 36 specimens

Family BYTHOCYTHERIDAE Sars, 1866

Bythoceratina Hornibrook, 1952

Type species. Bythoceratina mestayerae Hornibrook, 1952: 63, pl.16, figs 257–259,269.

Bythoceratina sp.

Figured specimen. Fig.6A (P311089)

Remarks. A large *Bythoceratina* species with a strongly calcified shell, acuminate posterior, arched dorsum and thick ventral rib, terminating posteriorly in a blunt spine or boss. This specimen is similar to *?Bythoceratina* sp.C (Neil 1992: 205, pl.18, fig.K) in its large size, heavily calcified shell and ventral rib, but the surface has no light reticulation as in the latter. It is quite different from other bythoceratines described from Australian Tertiary faunas, and from the lineages described by Hornibrook (1952) for New Zealand. In addition to this specimen, there is a fragment of another with a clear muscle scar pattern, and the characteristic ventral rib.

Measurements. P311089: L=0.88, H=0.52

Material. 1 specimen; 1 fragment (identifiable).

Hanaiceratina McKenzie, 1974

Type species. Bythocythere arenacea Brady, 1880: 142, pl.33, figs 3a-g (described as *Bythocythere arenosa*).

Hanaiceratina balcombensis McKenzie, 1974

Hanaiceratina arenacea balcombensis McKenzie, 1974:156, pl.4, figs 1–2, text-fig. 3i.
Hanaiceratina balcombensis Yassini & Jones, 1995: 324, figs 294–5,297,299–300.

Figured specimen. Fig.6B (P311090)

Remarks. In common with Yassini & Jones (1987, 1995) McKenzie's two subspecies (1974) are here regarded as separate species. Some of their figures seem to differentiate between the species also on the basis of the reticulation. The Skinner's specimens show the lateral shape of *H.balcombensis*, but also the less clean-cut reticulation of McKenzie's figure (1974, pl.4, fig.1). Other figured specimens (Yassini & Jones 1987, 1995) do not differentiate in this way, so that there is some confusion between the species (see particularly Yassini & Jones 1995: fig.295).

Measurements. P311090: L=0.68, H=0.36

Material. 4 specimens.

Debissonia Jellinek & Swanson, 2003

Type species. Cytheralison pravacauda Hornibrook, 1952: 66, pl.18, figs 283,284,287,289.

?Debissonia sp.

Remarks. Only two fragmentary specimens were found, both of the anterior portion of the valve. Although the reticulation is of the hexagonal/polygonal round style fossae diagnostic of *Debissonia* (i.e. not slit-like) and the characteristic large, elongate-oval foveola indicating the location of the central muscle scars are clearly visible, the absence of the posterior portion of the valve with the short caudal process diagnostic of *Debissonia* precludes definite attribution to this genus. (See Jellinek & Swanson 2003: 77). Breakage of *D.pravacauda* specimens is quite common (Neil 1992: 216), probably because the deep fossae produce some structural weakness in the shell,

in spite of its heavy calcification. Apart from its New Zealand occurrences *D.pravacauda* and an undescribed, but related species (see Jellinek & Swanson 2003: 76) occur in a number of Tertiary assemblages across southern Victoria and South Australia (Myaring Bridge, Muddy Creek, Warrambine Creek, Leigh River, Bells Headland, Angahook Member — Jan Juc and Port Campbell; Port Willunga, South Australia). None of the specimens in these assemblages has the posteroventral spine which Swanson & Jellinek (2203) regard as diagnostic of the genus *Cytheralison* s.s. Further study of these specimens will be necessary to clarify the distribution and range of the Family **Cytheralisonidae** Jellinek & Swanson, 2003 in southeast Australia. The fragments are not figured (P311091).

Material. 2 fragmentary specimens.

Family MACROCYPRIDIDAE G.W.Müller, 1912

Macrocypris Brady,1868

Type species. Cyhere minna Baird, 1850: 171, pl.20, figs 4a-d.

Macrocypris sp.1

Figured specimen. Fig.6C (P311092); 6D (P311092)

Remarks. Although there are some similarities of this specimen with other figured *Macrocypris* species from the region (e.g. *Macrocypris australiana* Neale, 1975: 11, pl.1, fig.11), mainly in terms of lateral shape, it is not possible to deem it conspecific with any of them on this criterion alone. Paracypridids share similar shapes, but may be differentiated on the basis of adont hinge or muscle scar patterns. But all macrocypridids share a merodont/entomodont hinge structure (van Morkhoven 1964; Maddocks 1990: 10). Maddocks's diagnosis of *Macrocyprina* (1990: 109) refers to small size and oblong shape, which would seem to rule out some Australian species designated *Macrocyprina* (Yassini & Jones 1987, 1995). *Macrocypris* sp.1 differs from *M.porcelanica* Whatley & Downing, 1983 in posterior and anterior shape, and in the non-porcelaneous shell.

Measurements. P311092: L=0.96, H=0.42

Material. 1 specimen (Specimen lost)

?Macrocypris sp.2

Figured specimen. Fig.6E (P311093)

Remarks. Since hinge structure and muscle scar pattern have not been determined for this specimen, allocation to *Macrocypris* on lateral valve shape alone can be only tentative.

Measurements. P311093: L=0.64, H=0.30

Material. 1 specimen.

Argilloecia Sars, 1866

Type species. Argilloecia cylindrica Sars, 1866: 18

Argilloecia sp.

Remarks. This specimen shows some similarity to *A.* sp.aff. *bulbifera* Müller, 1894 as described in Whatley & Downing (1983). No details of internal structure can be determined. Not figured (P311094)

Material. 1 specimen (Carapace).

Family PONTOCYPRIDIDAE G.W.Müller, 1894
Maddocksella McKenzie, 1982

Type species. Bythocypris tumefacta Chapman, 1914: 30, pl.6, figs 4a-c,5.

Maddocksella sp.

Remarks. The characteristic rounded, inflated oblong shape, and muscle scar pattern clearly indicate these specimens belong to *Maddocksella.* Not figured (P311095)

Material. 2 specimens.

DISCUSSION

The taxonomy of this assemblage provides data for comment on the cosmopolitan or endemic nature of the fauna and enables comparisons to be made at regional and provincial levels. The work of McKenzie, Warne and others on the Ostracoda of southeast Australia is acknowledged above. A previous study of fourteen Oligocene to Miocene ostracode assemblages from eight tectonic basins in this region (Neil

1995) was carried out at the generic level. Additional assemblages from Batesford Quarry, Myaring Bridge, Western Beach Geelong and theJemmy's Point Formation have since been picked and examined. Although further taxonomic and stratigraphic work on these additional assemblages will be necessary before adequate comparisons can be made, the ostracode faunas from the Tertiary and Quaternary beds (generally marls) represented show that characteristic genera can be identified. The commonest genera from this large region during mid-Tertiary times were *Hermanites, Quadracythere* and *Loxoconcha*. The Wuk Wuk Marl assemblage had *Neonesidea, Hermanites, Neobuntonia* and *Quadracythere* as its four most abundantly represented genera — indicating a general similarity with the regional pattern. These four genera contributed 44.9% of the total number of specimens. The proportion of rare species, defined as less than 1% (<5 specimens) of the total assemblage, is quite high (65% of the total number of species), yet the information provided by these species is considerable. Nearly 500 specimens were picked for this study, yet 22 species are represented by a single specimen. This rarity may be due to a number of factors such as small size, allochthonous origin, fragility of valves, unfavourable environment of deposition or collection and preparation procedures. Yet these factors apply to all such assemblages, and if rare species are ignored, information is lost. There is only one *Munseyella*, yet it provides a link with the Palaeocene Pebble Point fauna (Neil 2000a). Several Recent species (*Rotundracythere phaseolus, Loxoconcha trita, Semicytherura illerti*) are represented and give evidence of their persistence over much of the Neogene. Recent work on the dynamics of diversity (Matters of Record: Paleobiology 2003) underlines the significance of the need for the complete description of fossil faunas under standardised conditions, though whether patterns of local diversity can lend support to theories of global diversity is an open question. Johnson (Matters of Record: Paleobiology 2003: 20) has referred to a study of 42 samples from New Caledonia which revealed 2738 species of molluscs, yet one fifth of these species were represented by single specimens. Under these circumstances it is virtually impossible to ignore the occurrence of rare species.

The fact that of the species identified in the Wuk Wuk Marl assemblage only one is new, though previously found in the southwest of Victoria, 38 have occurred in other regional mid-Tertiary assemblages and only 17 species have been left in open nomenclature is a clear indication of this fauna being very representative of the region as a whole, if one is considering shallow-water marine environments.

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OVERLAND TRANSPORT OF LEAVES IN TWO FOREST TYPES IN SOUTHERN VICTORIA, AUSTRALIA AND ITS IMPLICATIONS FOR PALAEOBOTANICAL STUDIES

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The distance that leaves travel from their parent tree has important implications for palaeobotanical studies in which past vegetation types and climates are reconstructed. We quantified the distance moved overland by leaves of five tree species (*Acacia melanoxylon, Atherosperma moschatum, Eucalyptus regnans, Lomatia fraseri* and *Nothofagus cunninghamii*) in two contrasting, but contiguous, forest types in south-eastern Victoria: a) cool temperate rainforest dominated by Myrtle Beech, *Nothofagus cunninghamii*; and b) wet sclerophyll forest dominated by Mountain Ash, *Eucalyptus regnans*. Regardless of species, leaves generally remained close to their parent tree: 80 % of leaves moved less than 0.2 m over an observation period of six months and the greatest distance moved by any leaf was 3.4 m. Contrary to expectations, slope had little overall effect on leaf transport. We conclude that leaves from trees in these two forest types are transported less than one tree height from their parent tree during normal weather conditions. Greater transport may occur during extreme weather, which could promote extensive wind-borne leaf transport from the tree canopy.

Keywords: *Eucalyptus, Nothofagus*, palaeoclimate, taphonomic bias, wind transport, leaves

PLANT FOSSILS constitute a fundamental source of information on the evolutionary history of plant lineages, vegetation and climate change, however, taphonomic bias often complicates attempts to reconstruct palaeoclimates and past vegetation types. There are three main sources of preservational, or taphonomic, bias in the macrofossil record of plants (Spicer 1981, 1991; Ferguson 1985; Burnham 1989, 1993; Greenwood 1991; Burnham et al. 1992): a) differential production of plant parts (i.e., leaves, reproductive organs and woody parts); b) differential transport and sorting of plant organs among species once they have been shed from their parent plants; and c) differential decay and preservation of plant organs from different species.

In earlier papers we reported on differential production of plant parts (Steart et al. 2005) and differential aqueous transport of leaf material within streams (Steart et al. 2002). In this communication, we focus on differential overland transport of leaves belonging to tree species within two contrasting forest types. This aspect of taphonomic bias is important in palaeobotanical studies for two reasons. First, the accuracy with which a fossil-leaf deposit represents the original flora depends partly upon how far the component leaves were transported before burial and preservation (Ferguson 1985; Greenwood 1991; Spicer 1989, 1991). If little or no overland transport occurs after abscission, the leaf fossil record will reflect more accurately the local tree species than if leaves were moved large distances from their parent plant, or leaves were imported from distant plant communities (Ferguson 1985; Spicer 1989, 1991).

Second, if leaves move little after falling to the ground, fossil leaf assemblages should consist mostly of riparian or wetland plant species since these habitats are most conducive to leaf preservation (Spicer 1989, 1991). The prediction is especially important in the Australian context because there is a general paucity of sclerophyll taxa, such as *Eucalyptus* and *Acacia*, in the leaf fossil record (Cookson 1954; Christophel 1989; Lange 1982; Hill 1982, 1992, 1994; Martin 1994; Hill et al. 1999; Greenwood et al. 2000; Macphail & Hill 2001). These genera are not commonly considered as riparian. The extent of overland transport of leaves in

Australian forests needs to be assessed to determine if sclerophyll taxa have been excluded from fossil-forming processes because of lack of overland transport from their parent trees, or alternatively whether they were genuinely absent from an ancient community.

The role played by overland transport in controlling the species membership of the fossil assemblage is also critical in determining the accuracy and fidelity of palaeoclimate reconstruction. Several studies have shown, for example, that whereas the relative proportion of woody plants with toothed leaves is correlated with mean annual temperature, and thus can act as a proxy for palaeotemperature (Greenwood et al. 2004), local floristic patterns may confound this relationship (Burnham et al. 2001; Kowalski & Dilcher 2003; Greenwood 2005).

The published data on overland transport indicates that leaves are not spread far from their parent plant, with most abscissed leaves remaining within 10 to 20 metres of the bole of the parent (Spicer 1981, 1991; Ferguson 1985; Burnham et al. 1992; Greenwood 1991, 1992; Burnham 1994, 1997). Ferguson (1985) argued that, if leaves were relatively mobile after abscission, one would expect leaf litter on the forest floor to become increasingly well mixed with time. Several studies (e.g. Ferguson 1985; Burnham et al. 1992; Greenwood 1991, 1992; Burnham 1994, 1997) have shown that this does not happen. Indeed, the boundaries between the leaf halos of different tree species remain evident even after many months. Empirical studies undertaken outside of Australia also suggest that leaves move little from their parent plant once abscised. Ferguson (1985), for example, placed 500 spray-painted leaves of *Fagus sylvatica* in a closed woodland coppice of *Alnus glutinosa* and found that only one leaf had moved more than two metres after 98 days. In a later study, France (1995) found that coniferous pine needles and deciduous angiosperm leaves moved, on average, only ~ 0.3 m and ~ 0.5 m per year, respectively. In one of the few Australian studies, Carpenter and Horwitz (1988) reported limited overland transport of leaves in a Tasmanian rainforest, where the forest dominant species (*Eucalyptus obliqua*) was almost completely excluded from the detritus in a nearby stream, and by implication, the local macrofossil record. Furthermore, Greenwood (1991) found in tropical rainforest in northeastern Queensland that the large leaves (up to 15 x 1.5 cm) of the stenophyllous conifer *Prumnopitys amara* (Podocarpaceae) travelled further downslope (22 m) towards a stream than they travelled upslope (18 m), suggesting preferential downslope overland transport of the leaves of this species.

Spicer (1981) and Ferguson (1985) examined the factors controlling the overland transport of leaves. They concluded that leaf size had little affect on overland transport, whereas leaf weight and wetness, as well as wind speed, were major determinants. An implication of the effect of wind speed on overland transport is that leaves could be expected to move further in open (windy) than closed (relatively quiescent) forests. Long-distance transport via wind is especially important during catastrophic atmospheric events, such as hurricanes and tornadoes (van der Burgh 1994). A number of other studies also provide anecdotal evidence that leaves travel overland primarily via by wind blow or water wash under storm conditions (e.g. Drake & Burrows 1980; Dudgeon 1982 and Greenwood 1992). These factors probably interact strongly. Dudgeon (1982), for example, noted that delicate leaves, such as those of *Liquidambar formosana*, were most easily moved by gusts of wind. The slope of the land is likely also to be an important factor in leaf movement, as there is a positive relationship between bank slope and overland transport into streams (Fisher and Likens 1973; Sedell et al. 1974; Fisher 1977; Greenwood 1991; France 1995).

In this paper we report on a series of observations designed to quantify the distance travelled by leaves from a range of common tree species in two contrasting forest types in south-eastern Australia. Specifically, we tested four hypotheses: a) leaves would not travel substantial distances (>5 m) from where they were placed on the forest floor; b) this pattern would be evident across different plant species; c) leaves would travel further in open forest rather than closed forest; and d) leaves would travel greater distances over steep than level ground.

MATERIALS AND METHODS

Field site

Field experiments were undertaken at Cumberland Creek, in the Central Highlands of Victoria, south-eastern Australia (145°52'40", 37°33'28"; Fig. 1). The site has been described in Steart et al. (2002, 2005). As shown in Fig. 1, two contrasting forest types are present at the site: a) cool temperate rainforest (CTRF); and b) wet sclerophyll forest (WSF). Cumberland Creek flows through a shallow (~5–6 m deep) valley through the middle of the site. Slopes along the creek vary from 10° to 60°. The site has a

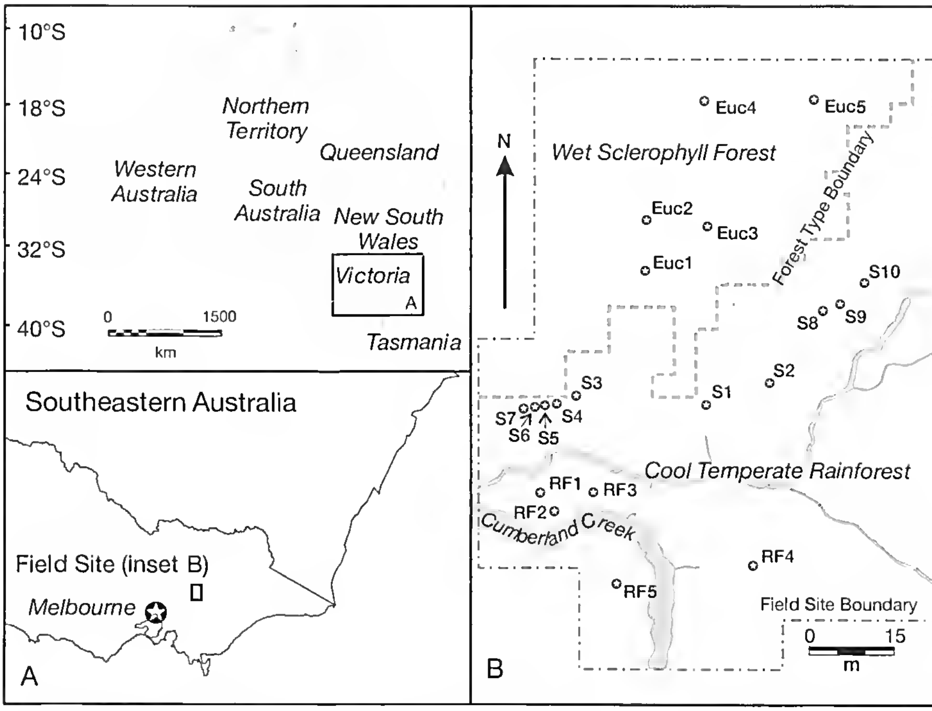

Fig. 1. Location of field site at Cumberland Creek in the Central Highlands of Victoria, south-eastern Australia. Fig. 1A shows the general location of the field site in southern Victoria; Fig. 1B shows a small-scale overview of the site, and shows the 20 locations where leaves were placed at the commencement of the experiment. These locations are cross-referenced to data in Table 3.

mean annual rainfall of ~1700 mm, and is subject to occasional winter snowfall.

Two tree species dominate the cool temperate rainforest: *Nothofagus cunninghamii* (Hook.) Oerst. and *Atherosperma moschatum* Labill. Some tall *Eucalyptus regnans* F.Muell. are scattered through the rainforest as emergent trees. In contrast, the wet sclerophyll forest surrounding the rainforest is dominated by *Eucalyptus regnans* with a subcanopy of *Acacia dealbata* Link. and *Acacia melanoxylon* R.Br. The shrub *Lomatia fraseri* R.Br. occurs occasionally across the site.

Leaf-transport protocols

Freshly abscissed leaves from the five species of forest tree (Table 1) were collected in fibreglass-mesh nets suspended beneath the various species. After collection, 400 leaves from each species were air-dried (~ 50 % relative humidity), weighed, then sprayed lightly with a bright pink fluorescent paint (White Knight Highlight Paint, Melbourne). Sprayed leaves were re-weighed to determine the effect of colour-tagging on leaf density; the paint increased the density of the leaves by 10 % to 55 % (Table 1).

The field experiment commenced in January 1999. In total, 2000 color-tagged leaves were tracked over six months. Twenty sets of 100 leaves, each consisting of 20 color-tagged leaves from each of the five tree species, were prepared. Leaves from ten sets were placed in a small pile around stakes on level ground in the two contrasting forest types, five packs in the cool temperate rainforest and five in the wet sclerophyll forest. To maintain spatial independence, each leaf set was at least 5 m from its nearest neighbour. Leaves from five sets were placed on steep sections of the creek valley floor, and the remaining five were placed on medium-sloped sections of the creek valley. The gradients of the slopes were determined trigonometrically; steep slopes were classified as 45° to 50°, and medium slopes as 20° to 30°. The ground cover at the steep locations consisted of a dense and tangled mat of the ferns *Blechnum wattsii* and *Polystichum proliferum*. Vegetation in three of the medium-slope sites consisted of dense *Blechnum wattsii*, while two sites consisted of

Species	Density before painting (g m^{-2})	Density after painting (g m^{-2})	Change in leaf density (%)
Acacia melanoxylon	183	209	14
Atherosperma moschatum	94	147	56
Eucalyptus regnans	243	268	10
Lomatia fraseri	121	140	15
Nothofagus cunninghamii	101	151	46

Table 1. Effect on leaf density of colouring leaves with spray paint.

bare ground with no ground-level vegetative cover. Such areas were atypical along the valley sides, but allowed us to distinguish between the effects on leaf transport of slope and vegetation cover.

The distance each leaf had moved from its initial starting location at the marker stake was measured after six months. Areas up to 10 m away from the stake were thoroughly searched for painted leaves. When identifiable leaves were recovered, the distance travelled was measured from the stake to the leaf petiole. In those cases where the leaves had decomposed over the six-month observation period, the distance from the marker to the shell of paint (where clearly identifiable) was measured.

Statistical analysis

Data were transformed with a $\log_e$ transformation, then analysed with a 2-way Analysis of Variance. For the calculation of F ratios, the site factor was considered a random factor within each location category and the species factor was considered as fixed (Zar 1984). Multiple regression was used to determine the variables that most influenced differences in transport among sites and species. The location variables tested were: a) forest type; b) density of the ground-level vegetation; c) flat versus steep slope; and d) medium versus flat and steep slope. The leaf variables tested were: a) leaf area; and b) average leaf weight (after painting). All statistical analyses were undertaken with Minitab 12 and the significant differences between the means determined with Tukey LSD post hoc tests.

RESULTS

Of the initial 400 leaves deployed for each species, the number of leaves recovered after six months varied from 314 for *Acacia melanoxylon* to 391 for *Lomatia fraseri* (Table 2). Of the leaves that were recovered, over 40 % stayed within 0.1 m of their original position at the marker stake and about 80 % remained within 0.2 m of their original position. The percentage of leaves that travelled less than 0.3 m over the six months ranged from 90 % (*Lomatia fraseri*) to 97 % (*Acacia melanoxylon*).

Table 3 shows the mean distance travelled by leaves of the five tree species at each of the 20 de-

	Distance class (cm)					
Number of leaves recovered for each distance class	0	0–9.9	10–19.9	20–29.9	30–39.9	> 40
Acacia melanoxylon (314)	38	127	100	40	5	4
Atherosperma moschatum (347)	31	129	113	51	11	12
Eucalyptus regnans (374)	34	121	131	52	20	11
Lomatia fraseri (391)	23	96	187	50	14	21
Nothofagus cunninghamii (337)	34	138	106	35	6	18

Table 2. Mean distances travelled by leaves as a function of tree species, pooled across all locations at the two forest types, shown for six different distance classes. Values in parentheses after species names refer to the number of leaves (of the original 400) recovered after six months.

Location	Forest Type	SC	VC	Acacia melanoxylon	Atherosperma moschatum	Eucalyptus regnans	Lomatia fraseri	Nothofagus cunninghammi
RF1	CTRF	F	B	0.06	0.09	0.13	0.11	0.09
RF2	CTRF	F	B	0.28	0.23	0.20	0.24	0.17
RF3	CTRF	F	B	0.07	0.11	0.12	0.09	0.11
RF4	CTRF	F	B	0.08	0.13	0.10	0.08	0.09
RF5	CTRF	F	B	0.26	0.21	0.37	0.46	0.43
Euc1	WSF	F	B	0.09	0.12	0.13	0.13	0.12
Euc2	WSF	F	B	0.09	0.07	0.09	0.13	0.04
Euc3	WSF	F	B	0.10	0.05	0.06	0.11	0.12
Euc4	WSF	F	B	0.18	0.20	0.40	0.27	0.17
Euc5	WSF	F	B	0.10	0.12	0.05	0.14	0.07
S1	CTRF	M	B	0.13	0.18	0.19	0.16	0.12
S2	CTRF	M	B	0.18	0.23	0.14	0.25	0.46
S8	CTRF	M	H	0.11	0.14	0.17	0.06	0.10
S9	CTRF	M	H	0.03	0.15	0.04	0.08	0.11
S10	CTRF	M	H	0.01	0.04	0.06	0.08	0.06
S3	CTRF	S	H	0.19	0.31	0.37	0.35	0.18
S4	CTRF	S	H	0.13	0.10	0.12	0.12	0.14
S5	CTRF	S	H	0.13	0.06	0.07	0.14	0.08
S6	CTRF	S	H	0.06	0.13	0.17	0.14	0.08
S7	CTRF	S	H	0.06	0.05	0.06	0.06	0.07

Table 3. Mean distances travelled by leaves as a function of tree species and deployment location at each of the two forest types. Abbreviations: CTRF = cool temperate rainforest; WSF = wet sclerophyll forest; RF = rainforest locations 1 to 5; Euc = wet sclerophyll forest locations 1 to 5; S = slope locations 1 to 10; SC = slope classification (F = flat, M = medium and S = steep); VC = Vegetation Coverage (B = bare ground and H = heavy ground cover). The positions of the 20 individual deployment locations used to quantify leaf transport are shown in Fig. 1C.

ployment locations at the field site; Fig. 2 shows the results of the 2-way ANOVA of these data. Analysed as a group, leaves of *Lomatia fraseri* at location RF5 and *Nothofagus cunninghamii* at location S2 in the cool temperate rainforest travelled the greatest distance (mean distances of 0.46 m). *Eucalyptus regnans* leaves in location S3, also in the cool temperate rainforest travelled the next greatest mean distance as a group, at 0.37 m. The greatest distance travelled by an individual leaf was 3.4 m; a single *Eucalyptus regnans* leaf from the wet sclerophyll rainforest at site Euc5. The ANOVA indicated that there was a significant difference (P < 0.001) in transport distances among sites (Fig. 2A). There was also a significant difference between tree species with respect to the distance travelled; *Lomatia fraseri* was significantly different from *Acacia melanoxylon*, but there were no significant differences in distance travelled among the other three species (Fig. 2B). This apparently contradictory result is probably a function of low statistical power of the post-hoc tests in comparison with ANOVA.

Eleven different regression models were tested, each including a different subset of variables (Table 4). The best fits ($r^2 = 0.226$ and $r^2_{adj} = 0.185$) were obtained with Model 9, which incorporated five of the six possible variables. (Leaf weight was not included in the regression equation because it was correlated with leaf area.) Only two of these five variables were significant: vegetation coverage ($t = 2.79$, $P = 0.006$), and b) medium versus flat/steep

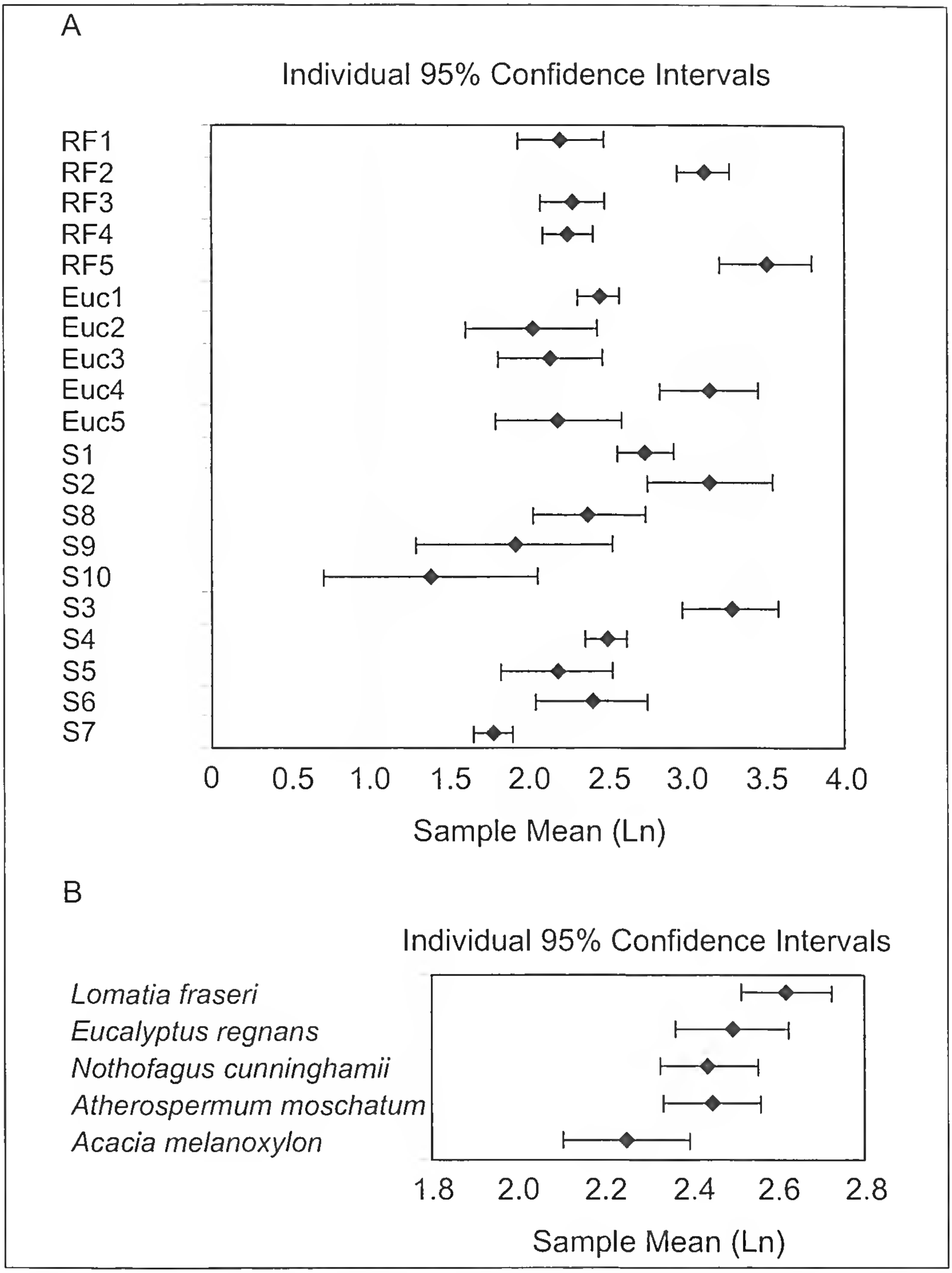

Fig. 2. Graphical representation of statistical analysis (2-way ANOVA) of the mean distances travelled by leaves as a function of tree species and location at each of the two forest types. Fig. 2A shows the analysis of mean distance travelled in terms of site comparisons; Fig. 2B shows the comparison across species. Distances were $\log_e$ transformed prior to analysis. Error bars show the 95 % confidence limits.

Model	r^2	r^2_{adj}	Cp	SD	Variables included LA	LW	FT	VC	S1	S2
1	8.1	7.2	14.6	0.61895						X
2	2.1	1.1	21.8	0.63879	X					
3	18.0	16.3	4.7	0.58780				X		X
4	12.7	10.9	11.1	0.60644			X			X
5	20.1	17.6	4.2	0.58319	X			X		X
6	19.8	17.3	4.5	0.68404			X	X		X
7	22.0	18.7	3.9	0.57931	X		X	X		X
8	21.1	17.7	5.0	0.58260		X	X	X		X
9	22.6	18.5	5.1	0.57983	X		X	X	X	X
10	22.0	17.9	5.8	0.58207	X	X	X	X		X
11	22.7	17.7	7.0	0.58262	X	X	X	X	X	X

Table 4. Results for best-subset regressions for the mean transport data shown in Table 3. Abbreviations for statistical terms: r^2 indicates the percentage of the variation in the data explained by the regression equation; r^2_{adj} is the adjusted r^2, which takes into account the number of variables in the regression; Cp is a measure of the predicted error of the regression equation; and SD is the standard deviation. Abbreviations: LA = Leaf Area; LW = Leaf Weight; FT = Forest Type; VC = Vegetation Coverage; S1 = Flat versus Steep Slope; S2 = Medium versus Flat/Steep Slope. The X symbol in a cell indicates that the stated variable was included in the regression analysis.

slope ($t = -4.441$, $P < 0.001$). The best-fit regression equation (Model 9) was:

$$\begin{gathered}\text{Log (distance moved)} = 2.92 + 0.00763 \text{ (Leaf area)} \\ - 0.2803 \text{ (Forest type)} + \\ 0.4033 \text{ (Vegetation coverage)} - \\ 0.0437 \text{ (Flat versus steep slope)} - \\ 1.0489 \text{ (Medium versus flat/steep Slope)}\end{gathered}$$

We also tested the application of a full quadratic model to determine whether the addition of cross-product or squared terms would improve the regression model but it did not. The only terms allowed in the analysis were quadratic terms for the leaf variables and interaction terms between the leaf variables and the location variables. Only the linear terms ($F_{6,83} = 2.66$, $P = 0.021$) were significant; the quadratic terms ($F_{2,63} = 0.68$, $P = 0.507$) and the interaction terms ($F_{8,63} = 0.24$, $P = 0.982$) were not.

The regression analysis indicates that both the abundance of the ground vegetation and some aspects of slope (i.e, medium versus flat/steep slope only) were significant predictors of overland leaf transport. In other words, leaves of all tree species travelled greater distances on the medium-slope sites with no ground-level vegetation than they did on medium-slopes sites with abundant ground-level vegetation. Conversely, the area of the leaves was not a significant factor, nor did forest type or flat versus steep slopes explain the extent of overland transport. It is possible that these results may be a function of the very small distances travelled in what is a rather closed environment with substantial hydrodynamic roughness and the consequent very low wind velocities.

DISCUSSION

We aimed to test four hypotheses in this field experiment: a) leaves would not travel substantial distances (>5 m) from where they were placed on the forest floor; b) this pattern would be evident across different plant species; c) leaves would travel further in open forest rather than closed forest; and d) leaves would travel greater distances over steep than level ground. In terms of the first prediction, we found that leaves of all species travelled little once they had fallen to the ground. The maximum distance travelled overland in six month by any leaf was 3.4 metres, and over 80 % of leaves moved less than 0.2 m. This finding, of negligible leaf transport, accords well with the reports of Spicer (1981), Ferguson (1985) and France (1995).

Our third hypothesis was that leaves would travel further in open forest rather than closed forest, related to likely differences in exposure and wind speed. In this case we found no statistically significant differences in mean transport distance between the two forest types, and conclude that the 'openness' of the wet sclerophyll forest in comparison with rainforest had little or no impact on the transport of leaves on the ground.

Our fourth hypothesis posited that leaves would travel greater distances over steep than level ground. There was increased leaf transport down the medium slopes in the cool temperate rainforest sites, but only where the slopes had no ground vegetation cover. The limited distances involved, however, indicate that the assertions made by Sedell et al. (1974) and Fisher and Likens (1973), of a strong positive relationship between slope and overland transport, must be questioned where leaves move over dense ground vegetation. The effect of slope on leaf transport distance was difficult to interpret and, in any case, quite small even if statistically significant (Table 3); here the maximum mean distances among sites are in the order of only tens of centimetres. The effect of the density of the ground vegetation was significant, with the ANOVA and the regression model both indicating a statistically significant effect. This result is largely in accordance with Ferguson (1985), who suggested that, as ground vegetation became thicker, the likelihood of travel declined because there were more obstructions upon which leaves could become captured. Seen overall, our results indicate that even for the steep sides in heavily vegetated valleys, overland transport is insignificant.

The small scale of movement in both the open vegetation of the wet sclerophyll forest and in the closed vegetation of the cool temperate rainforest suggests that the movement of leaves via wind-assisted lateral transfer is very low in these two forest types. It is probable that the high humidity and rainfall of both forest types played a role in this result; Spicer (1989) and Ferguson (1985) noted that moisture not only increased the weight per unit area of a leaf but causes leaf-to-leaf adherence, and the resultant leaf mass remains resistant to transport.

The ANOVA results indicate some differences in transport across species, and thus did not provide unequivocal support for our second hypothesis regarding among-species differences. There was a significant difference in mean transportation distances between *Lomatia fraseri* and *Acacia melanoxylon*, but not among the other species. This effect raises the theoretical possibility of differential sorting between the various tree species, though the results of regression analysis suggest that this is not linked to leaf area. In practice, the effect in the forest systems examined would probably be very small, since once the leaves had fallen to the ground, no leaves travelled far enough for differential sorting to have a pronounced effect. The location in the forest most likely to present an opportunity for differential sorting is on the immediate banks of the stream. Here transport distances to an aquatic systems (and hence a potential site of deposition) are very short, and slight enrichment of one species over another are possible.

It is plausible that, in many forested streams, the leaf litter being transported would be mostly derived from the riparian vegetation growing along their banks. Hence, waterways flowing through vegetation communities which are mainly sclerophyllous in nature, but which have bands of mesic riparian forest following the watercourses, would have little input from the surrounding sclerophyllous vegetation. Under these conditions any fossil deposits resulting from such communities would reflect the mesic riparian vegetation and not the surrounding sclerophyllous communities. This effect may partly explain the relative paucity of *Eucalyptus* and *Acacia* leaves in the Australian plant-fossil record. These taxa may have been present, maybe even common, in the landscape from Oligocene/Miocene times onwards, as evidenced by the existence of their pollen records (Martin 1994). However if these species grew mainly on ridges and areas not immediately adjacent to local watercourses, macrofossils would be rare since their leaves lack the ability to disperse over significant distances overland.

An additional outcome stemming from our observations is that the proportion of species with toothed leaf margins found in a fossil assemblage will reflect the leaf margin proportion of the riparian vegetation, and not that of the interior forest. The leaves of the forest interior are largely unable to be transported overland into the stream, thus explaining in part the discrepancy noted by Greenwood (2005) in the proportion of species with toothed leaf margins between samples collected from the streambed and those from the forest interior in Australian wet forests sites. This bias towards the riparian vegetation must be considered when reconstructing the species composition of the palaeovegetation or using the relative proportion of leaf margin type (or other

species attribute) to reconstruct climate, based on a fossil leaf assemblage.

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PUBLIC LAND USE PLANNING USING BIOREGIONS AND OTHER ATTRIBUTES: DETERMINING THE STUDY AREA OF THE VEAC RIVER RED GUM FORESTS INVESTIGATION

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In order to plan for the best use of public land at a regional scale the determination of an appropriate regional boundary is important for ecological, resource use and recreational reasons. The study area for the Victorian Environmental Assessment Council's (VEAC) River Red Gum Forests Investigation incorporated bioregional boundaries, modelled pre-1750 vegetation distribution, recent public land use investigations, and the distribution of public land. This paper outlines how ecological attributes and past land use studies were used to inform the boundary for this major study of public land along the Murray River in northern Victoria.

Keywords: Land use planning, bioregions, Ecological Vegetation Classes, riverine forests, Riverina, Murray River

To more efficiently achieve conservation goals a systematic and landscape-scale approach to biodiversity conservation is required (Margules & Pressey 2000). In order to undertake effective and systematic conservation planning exercises, the delineation of appropriate regional boundaries in which to carry out such exercises is of particular importance. Ideally, these regions encompass the full range of ecological elements in the landscape which are the target of such assessments.

In Australia, conservation planning is often used as part of broader public land use planning exercises. A key feature of conservation planning is the establishment of a reserve system which samples biodiversity in a comprehensive, adequate and representative (CAR) manner. All Australian States and Territories have been working toward the development of a CAR system of protected areas since signing the international Convention on Biological Diversity (1992) and the *National Strategy for the Conservation of Australia's Biological Diversity* (Commonwealth of Australia 1996). This has been guided by nationally agreed criteria for the establishment of a comprehensive, representative and adequate (CAR) reserve system (JANIS 1997, NRMMC 2005).

This paper outlines how various ecological attributes were used in conjunction with the location of past land use studies to determine a study area which encompasses the riverine forests and related environments of northern Victoria.

THE RIVER RED GUM AND BLACK BOX FORESTS OF NORTHERN VICTORIA

The Murray River and associated inflowing rivers of northern Victoria and southern New South Wales are characterised by forests and woodlands dominated by River Red Gum *Eucalyptus camaldulensis* and Black Box *E. largiflorens*. These forests form an important ecological corridor in a largely cleared surrounding landscape and habitat in their own right for a suite of sedentary and migratory species (Loyn 1985; State of Victoria 1997; Bennett et al. 1998; Eardley 1999; Ballinger & Yen 2002; Koehn 2002; Loyn et al. 2002). The forests not only provide important habitat for a range of forest-adapted fauna, but also act as a pathway for extending the geographic range of a number of species, particularly avifauna (e.g. Tzaros 2001). The forests also provide an important area for recreational activities such as camping and for the use of natural resources such as timber. River Red Gum and Black Box also dominate large areas of floodplain wetlands and non-riverine

wetlands in northern Victoria and southern NSW. These include the large internationally important wetlands, Barmah Forest and Gunbower Forests in Victoria and the NSW Central Murray State Forests, which are inundated during Murray River flood events. These wetlands provide a number of important ecological functions in the Murray River system, including providing habitat for native fish and water birds, improving water quality (filtering nutrients and salt) and carbon cycling (Young 2001).

HISTORIC PUBLIC LAND USE PLANNING IN THE MURRAY RIVERINE FORESTS

Since 1971, the Victorian Environmental Assessment Council (VEAC) and its predecessors, the Land Conservation Council (LCC) and Environment Conservation Council (ECC), investigated the best use of public land in a systematic region-by-region approach across Victoria. The recommendations of the LCC, ECC and VEAC were presented to the government and are reflected in the distribution of parks and reserves, state forests and other public land we see in Victoria today.

Regional public land use planning investigations by the former LCC were carried out within administrative boundaries often based on Forest Commission regions and with local government borders. The ECC more recently studied public land use within more ecosystem-based study areas (i.e. Box-Ironbark Forests and Woodlands, and Marine, Coastal and Estuarine).

The riverine forests of the mid-Murray and associated rivers and much of the surrounding plains have not been subject to a public land use investigation for more than 20 years, the longest for any part of the State[1]. The Barmah and Gunbower forests, were last subject to a public land use investigation in 1985 (in the LCC Murray Valley Investigation; LCC 1985), while recommendations on the use of riverine forests north of Kerang to the South Australian border were made in 1989 (LCC 1989). Yet other smaller areas of the Riverina have not been investigated since the early-mid 1980s (LCC 1981; LCC 1986). Other special investigations assessed the values of these areas for river, stream and catchment values and wilderness values (LCC 1991a; LCC 1991b). More recently, the North East Regional Forest Agreement process considered public land upstream of the Ovens River (Commonwealth of Australia & State of Victoria 1999), while management planning in State Forests in the region has seen an increase in the area zoned for conservation (NRE 2002; DSE 2004).

THE RIVER RED GUM FORESTS INVESTIGATION

In 2002, the Australian Labor Party made an election commitment to provide a reference to the Victorian Environmental Assessment Council to investigate the creation of a chain of multiple use parks on public land along the Murray River from Yarrawonga to Swan Hill and a uniform management regime for the Murray with NSW (ALP 2002). In December 2004, the Victorian Government released draft terms of reference for a study of these ecosystems by VEAC for public comment. The proposed study area covered the forests on public land between Swan Hill and Yarrawonga, taking in the Barmah, Gunbower and lower Goulburn Forests (Fig. 1). This area encompassed approximately 80,500 ha of public land.

More than 2,000 submissions on the draft Terms of Reference were received from a wide range of stakeholders and interested parties. The majority of submissions on the draft Terms of Reference were in favour of including all major riverine red gum forests on public land[2] along the Murray River corridor from the Hume Weir to the South Australian border. After considering the submissions received, the government decided to expand the study area.

This interest in expanding the study area allowed the opportunity to establish a boundary using a more ecosystem-based approach. Considering a larger area of the target ecosystem also allows flexibility in the range of recommendations that may be developed. For example, by considering resource use and recreation across the entire ecosystem provides more room to balance competing demands for public land and potentially avoids shifting uses and conflicts to those parts of the ecosystem outside of the study

1 The rest of the State has been subject to at least one public land use investigation since that time, either through the LCC/ECC/VEAC process or the Regional Forest Agreement process.

2 Public land is defined under the *Victorian Environmental Assessment Council Act 2001* and includes Crown land and land vested in any public authority (with the exception of a municipal council and some land managed by water authorities).

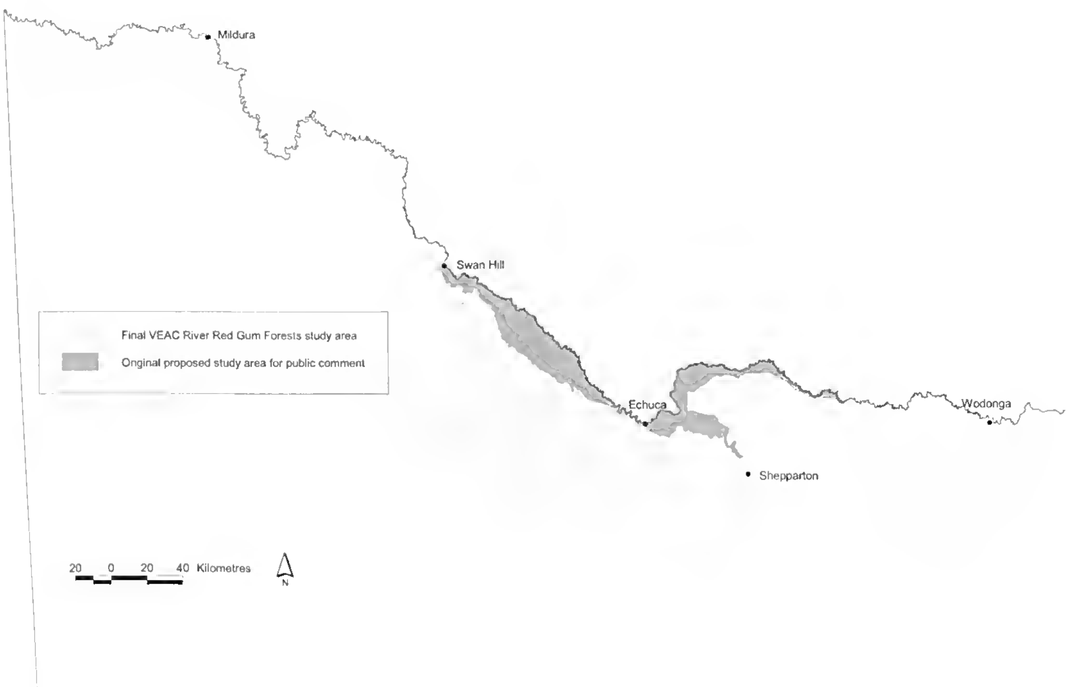

Fig. 1. Proposed and final study area boundaries for the VEAC River Red Gum Forests Investigation

area. Furthermore, it provides a sound basis for comparative assessments of Ecological Vegetation Class representation within the reserve system, internal consistency and distinct differences between areas in and outside of the study area.

As a result a number of options for expanding the study area were considered. Four main attributes for determining the final boundary were used: 1) Victorian bioregional boundaries (2002), 2) modelled occurrence of pre-1750 Ecological Vegetation Classes, 3) location of recent public land use studies, and 4) public land.

The means in which these attributes were incorporated into the final River Red Gum Forests Investigation study area boundary are outlined below. All datasets were sourced from the Department of Sustainability and Environment's Corporate Geospatial Data Library and analysed within ArcView GIS 3.3.

Bioregional boundaries

Bioregions are the broadscale mapping units for biodiversity planning in Victoria and capture the patterns and ecological characteristics in the landscape. Victorian Bioregions nest within the national categorisation for terrestrial environments, the Interim Biogeographic Regionalisation of Australia (IBRA) where they are known as 'subregions' (Thackway & Cresswell 1995; Environment Australia 2000). There they act as a framework for assessing representativeness in the reserve system.

The floodplain forests along the Murray fall within four main Victorian Bioregions — the Murray Fans, Murray Scroll Belt, Robinvale Plain and Victorian Riverina (Fig. 2). All Victorian bioregions fall within the national 'Riverina' IBRA bioregion. Three of these bioregions (subregions) also straddle the border with New South Wales and the Murray Scroll Belt continues into the Riverland country of South Australia.

Within Victoria, the Murray Fans bioregion, which occurs between the junction of the Ovens and Murray Rivers in the east and Narrung in the west incorporates the Barmah, Gunbower, lower Goulburn and Nyah forests. The Robinvale Plain bioregion is situated between Narrung and Mildura takes in part of the Hattah-Kulkyne National Park, while the Murray Scroll Belt to the west of Mildura and includes Wallpolla and Lindsay Islands. The Victorian Riverina bioregion borders the Murray between the Ovens and Kiewa Rivers and incorporates much of

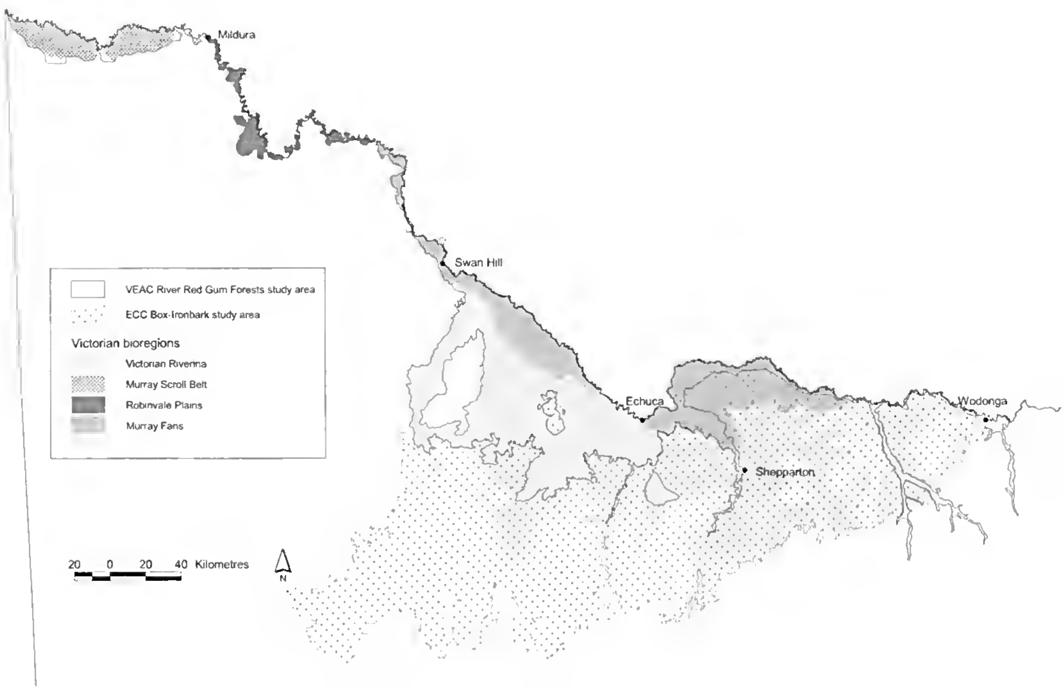

Fig. 2. Location of Victorian bioregions and the ECC Box-Ironbark study area in relation to the VEAC River Red Gum Forests study area.

the Northern Plains south of the Murray Fans bioregion.

The Robinvale Plain and Murray Scroll Belt bioregions incorporate almost all of the pre-1750 extent of the Riverine Grassy Forests and Woodland along the Murray River downstream of Swan Hill (see below).

Modelled occurrence of pre-1750 Ecological Vegetation Classes

Ecological Vegetation Classes (EVCs) are a type of native vegetation classification described through a combination of floristics, life forms and ecological characteristics, and through an inferred fidelity to particular environmental attributes. Since the mid-1990's, it has been the principal unit for vegetation circumscription and mapping for land-use planning and management in Victoria (Woodgate et al. 1996; Parkes et al. 2003).

Modelling of the predicted pre-1750 distribution of EVCs allows for comparisons of past and current extents and thus determination of levels of depletion prior to European settlement. Based on this, priority setting for those EVCs most in need of increased protection can occur. In the north west of Victoria, pre-1750 EVC modelling used soils, climate, terrain and flooding regime combined with current and historical records to spatially model vegetation distribution prior to clearing (see White et al. 2003).

'EVC groupings', which incorporate a number of related EVCs, were used to illustrate the distribution of vegetation in northern Victoria. Of particular interest was the pre-1750 distribution of the 'Riverine Grassy Woodlands or Forests' and 'Wetlands' EVC groups as these classifications incorporated the River Red Gum and Black Box forests and woodlands and associated floodplain wetlands. Also of interest was the distribution of the 'Plains Grasslands and Chenopod Shrublands' EVC group as Northern Plains Grasslands are one of the most threatened ecological communities in Victoria (see Table 1 for constituent EVCs within each of these groups and Fig. 3 for distribution).

The Riverine Grassy Woodlands or Forests occurred mainly within the Murray Scroll Belt, Robinvale Plain and Murray Fans bioregions, but also along the Kiewa, Ovens, Goulburn, Loddon and Avoca Rivers. Plains Grasslands occurred mainly in

Riverine Grassy Woodlands or Forests	Wetlands	Plains Grasslands and Chenopod Shrublands
Creekline Grassy Woodland	Billabong Wetland	Alluvial Plains Semi-arid Grassland
Drainage-line Complex	Billabong Wetland/Red Gum Wetland Mosaic	Chenopod Grassland
Floodplain Riparian Woodland	Cane Grass Wetland	Low Chenopod Shrubland
Floodway Pond Herbland/Riverine Swamp Forest Complex	Disused Floodway Shrubby Herbland	Plains Grassland
Grassy Riverine Forest	Floodplain Grassy Wetland	Plains Savannah
Grassy Riverine Forest/Floodway Pond Herbland Complex	Floodway Pond Herbland	
Grassy Riverine Forest/Riverine Swamp Forest Complex	Freshwater Lake Mosaic	
Intermittent Swampy Woodland	Lake Bed Herbland	
Lignum Shrubland	Lignum Wetland	
Lignum Swampy Woodland	Moira Plain Wetland	
Lignum Swampy Woodland/Lake Bed Herbland Mosaic	Plains Grassy Wetland	
Lignum Swampy Woodland/Plains Grassland Mosaic	Red Gum Wetland	
Riverine Chenopod Woodland	Red Gum Wetland/Plains Grassy Wetland Mosaic	
Riverine Chenopod Woodland/Lignum Wetland Mosaic	Reed Swamp	
Riverine Chenopod Woodland/Plains Grassland Mosaic	Shallow Freshwater Marsh	
Riverine Grassy Woodland	Spike-sedge Wetland	
Riverine Grassy Woodland/Plains Woodland Complex	Tall Marsh	
Riverine Grassy Woodland/Plains Woodland/Gilgai Wetland Complex	Wetland Formation	
Riverine Grassy Woodland/Plains Woodland/Riverine Chenopod Woodland Complex		
Riverine Grassy Woodland/Riverine Chenopod Woodland/Wetland Mosaic		
Riverine Grassy Woodland/Sedgy Riverine Forest/Wetland Formation Mosaic		
Riverine Swamp Forest		
Riverine Swampy Woodland		
Riverine Swampy Woodland/Lignum Wetland Mosaic		
Sedgy Riverine Forest		
Sedgy Riverine Forest/Riverine Swamp Forest Complex		

NB: EVC Groupings have been established by DSE for more convenient illustration and management of statewide vegetation data. Smaller occurrences of a number of other Ecological Vegetation Classes also fall within the study area. It is worth noting that more recent vegetation mapping of the Barmah forest by Frood (2005) has identified EVCs at a finer scale than past mapping for Barmah Forest (see also VEAC 2006).

Table 1. EVC Groupings (and constituent EVCs) within the expanded River Red Gum Forests Investigation study area.

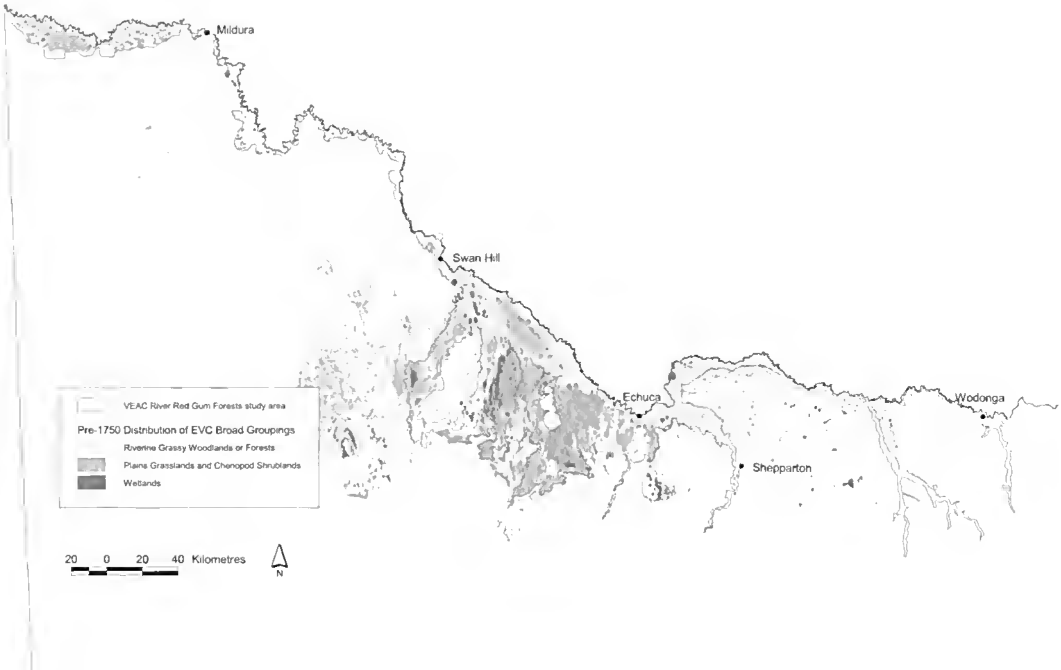

Fig. 3. Pre-1750 distribution of Riverine Grassy Woodlands or Forests, Plains Grasslands and Chenopod Shrublands, and Wetlands EVC broad groupings in and surrounding the VEAC River Red Gum Forests study area

the Victorian Riverina bioregion and particularly around the Patho Plains. Wetlands were scattered throughout the region, with larger occurrences near the Loddon River, Corop Lakes, Kerang Lakes and Barmah Forest. In designing the study area a 100 m buffer was applied to the 'Riverine Grassy Forests or Woodlands' EVC group to ensure the riverine corridors were represented as consolidated units.

Location of recent public land use investigations

The Environment Conservation Council's Box-Ironbark Forests and Woodlands Investigation included the box-ironbark forests and woodlands on the inland hills and on the elevated terraces of the Northern Plains but did not include the native grasslands on the elevated terraces or River Red Gum or Black Box forests and woodlands on the lower elevation floodplains (ECC 1997, see Fig. 2). Specifically, the Box-Ironbark study area was based on a combination of the modelled pre-1750 distribution of Broad Vegetation Types (a coarser vegetation classification than EVCs) which were allocated to land systems in the area, and modelled pre-1750 EVCs where available (see ECC 1997, particularly Maps D and E from that report). This resulted in some areas within the broad Box-Ironbark study area being excluded (e.g. the Corop Lakes area and the Ovens, King, and parts of the Goulburn and Campaspe Rivers).

As the Box-Ironbark investigation was only recently completed after extensive public consultation (ECC 2001), and with terms of reference similar to the River Red Gum Forests Investigation, reinvestigating the relatively small areas of riverine EVCs was not considered desirable. Exceptions to this were where small parts of larger riverine forest blocks were included in the Box-Ironbark study area due to the coarse nature of that mapping (e.g. Barmah Forest near the Barmah township).

Public land

The River Red Gum Forests Investigation only considers public land within the study area. Consequently it was important to ensure that all key blocks of public land likely to contain suitable vegetation were included in the study area. Where the ecological boundaries of the study area have intersected mainly

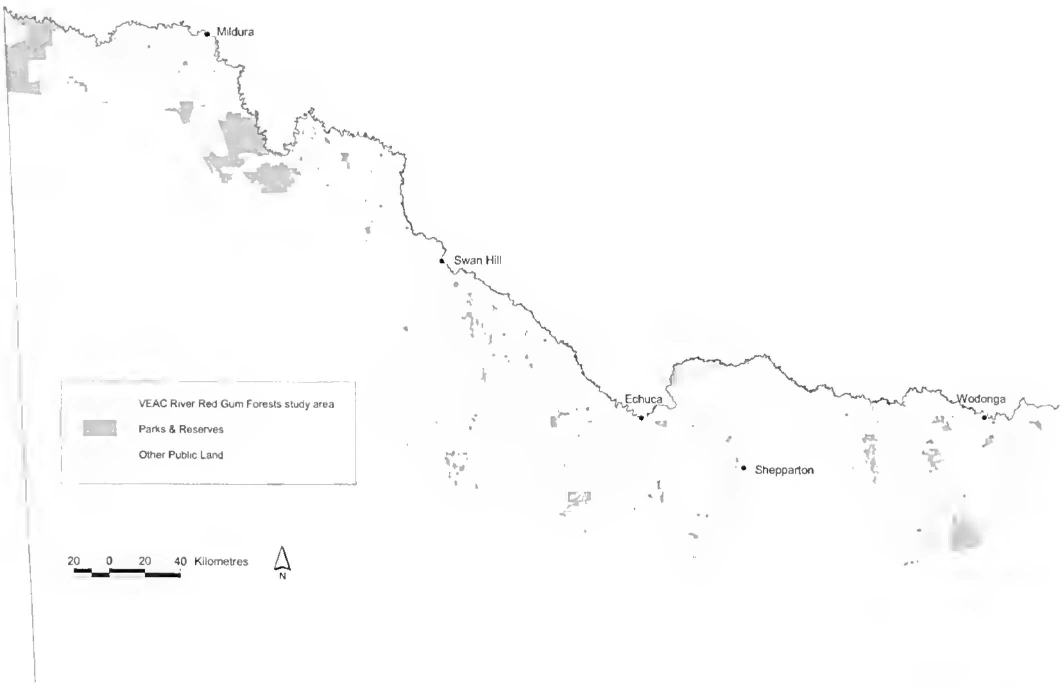

Fig. 4. Distribution of existing public land (including parks and reserves) in and surrounding the VEAC River Red Gum Forests study area

small parcels of public land, the boundary has been adjusted to incorporate the entire public land parcel (see Fig. 4). This will ensure a consistent and integrated assessment of those public land parcels.

DETAILS OF THE EXPANDED RIVER RED GUM FORESTS INVESTIGATION STUDY AREA

The decision to expand the study area to include all riverine forests along the Murray River and its tributaries provides a unique opportunity to consider the protection of endangered ecosystems occurring on public land in the surrounding plains. The Victorian Riverina is considered to be a high priority bioregion for increased conservation assessment and action (State of Victoria 1997; Environment Australia 2000). Due to the relatively small amount of public land remaining in this bioregion and the high conservation value it potentially represents, incorporation of this bioregion into the larger study area was considered desirable.

Based on the ecological and landform attributes, the location of recent public land use investigations and distribution of public land described above, the expanded River Red Gum Forests investigation study area was designed to broadly encompass the following: all the Murray Scroll Belt and Robinvale Plain bioregions, and the sections of the Murray Fans and Victorian Riverina bioregions not covered by the ECC Box-Ironbark investigation, with slightly widened corridors around parts of the Ovens, Goulburn and Campaspe Rivers. While only public land within the study area is considered in the investigation, all vegetation types occurring on that public land will be investigated (i.e. not just those vegetation types discussed above).

Specifically, the boundary is defined as the following:

Northern boundary

- Follows the Murray River from South Australian border to the western edge of Lake Hume. Mapping of the Murray River has been undertaken at different spatial and temporal scales for different purposes in the past. Nonetheless, the northern boundary of the study area will always be the high water mark on the Victorian side of the Murray River west of Lake Hume.

EVC Group	Area on public land (ha)	
	Proposed Terms of Reference	Final Terms of Reference
Riverine Grassy Woodlands or Forests	58,960	137,430
Plains Grasslands and Chenopod Shrublands	40	16,680
Wetlands	2,770	12,640
Plains Woodlands or Forests	2,590	23,660
Mallee	–	6,780
Riparian Forests or Woodlands	150	6,730
Salt-tolerant and/or succulent Shrublands	–	1,470
Dry Forests	–	70
Lower Slopes or Hills Woodlands	–	60
Rounded to nearest 10 ha. Note: does not include EVCs on recent land purchases.		

Table 2. Area of extant EVC Groups occurring on public land in the proposed and final study areas.

Southern boundary (from east to west):

- South of Lake Hume, *Victorian Riverina* bioregional boundary along the Kiewa River.
- West of Wodonga to Ovens River: Riverine area not covered by the ECC Box-Ironbark Investigation.
- Ovens (and King) River corridors follows the ECC Box-Ironbark boundary and then *Victorian Riverina* bioregional boundary in the upper reaches. Slight buffering of pre-1750 EVCs and alignment to roads has occurred in some areas.
- The area of the *Murray Fans* bioregion not included in the ECC Box-Ironbark boundary (from Bundalong to east of Barmah township), with minor adjustments to follow roads.
- The Goulburn River corridor to below the Nagambie Weir.
- The Murray Fans from near Undera to below Kanyapella Basin.
- The area of the *Victorian Riverina* bioregion not included in the ECC Box-Ironbark boundary (between Kanyapella Basin and Kerang, including the Corop Lakes system, and the Campaspe River corridor to north of Barnadown).
- *Murray Fans* bioregional boundary from Lake Boga to Narrung.
- *Robinvale Plain* bioregional boundary from Narrung to Mildura.
- *Murray Scroll Belt* bioregional boundary from Mildura to South Australian border.

KEY FEATURES OF THE RIVER RED GUM FORESTS STUDY AREA

The expanded study area covers approximately 268,000 ha of public land, an increase of approximately 187,000 ha from the draft terms of reference. This has resulted in significantly more of the key ecosystems which occur on public land to be considered (Table 2). Key blocks of public land along the Murray include Barmah, Gunbower, Nyah, Hattah Lakes, Wallpolla Island and Lindsay Island. The study area also includes important River Red Gum and Black Box Forests along seven major rivers flowing into the Murray — the Avoca, Loddon, Campaspe, Goulburn, Ovens, King and Kiewa. The Ovens and Goulburn are Heritage Rivers and the former is one of the least regulated rivers in the Murray-Darling system. Four of Victoria's 11 Ramsar Wetlands of International Importance occur within the study area (i.e. Hattah Lakes, Kerang Lakes, Gunbower Forest and Barmah Forest), as do numerous wetlands listed on the Directory of Important Wetlands in Australia (Environment Australia 2001). Further, of the six 'icon sites' identified by the recently-established Living Murray initiative (which aims to improve the health of the Murray River and adjoining ecosystems), five at least partly fall within the study area.

The Victorian Riverina bioregion contains numerous relatively small but ecologically important blocks of public land containing endangered native

grassland and wetland communities (e.g. grasslands in Terrick Terrick/Patho Plains region, Corop Lakes and Kerang Lakes). Within the Victorian Riverina a number of significant private properties have recently been acquired for the purpose of nature conservation as part of a strategic land purchase program by the Department of Sustainability and Environment (see Fitzsimons & Ashe 2003; Fitzsimons et al. 2004; Fitzsimons et al. 2006).

PUBLIC LAND USE PLANNING AT A LANDSCAPE SCALE: CONCLUDING COMMENTS

This paper presents details on the practicalities of determining study areas for public land use investigations based on bioregions and other attributes. The expanded boundary for the VEAC River Red Gum Forests Investigation study area allows for a sound comparative assessment of the reservation status of riverine and plains vegetation communities and habitats across northern Victoria. The inclusion of areas of plains grassland, plains grassy woodland and chenopod shrubland, some of the State's most depleted vegetation communities, is of particular significance. Some of these areas have not had a public land use investigation since 1985 and knowledge of their ecological processes and need for increased conservation has grown greatly since this time. However, to ensure that various components of biodiversity are well represented in reserves or by other protective measures, ecological surrogates may have to be considered as hierarchies (e.g. landscape, EVC, fine-scale habitat) to ensure general representativeness (as shown for Box-Ironbark ecosystems; Mac Nally et al. 2002).

Following the release of a discussion paper and draft proposals paper, both involving rounds of public consultation, the Victorian Environmental Assessment Council will make recommendations to the Victorian Government on public land use in the region, in accordance with its terms of reference. It is important to note that while the boundary for the VEAC River Red Gum Forests Investigation study area largely reflects ecological attributes of the riverine and plains systems of northern Victoria, similar and intricately linked ecosystems occur north of the Murray River in New South Wales (and along the Murray corridor into South Australia). Although not the subject of the VEAC investigation, consideration of current and potential future land use in NSW (and to a lesser extent, South Australia), will nonetheless be important if land use decisions in Victoria are to be effective at a landscape scale.

For full details on the VEAC River Red Gum Forests Investigation see http://www.veac.vic.gov.au.

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PALAEOGENE OSTRACODA (CRUSTACEA) FROM THE WANGERRIP GROUP, LATROBE-1 BORE, OTWAY BASIN, VICTORIA, AUSTRALIA

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EGLINGTON, C., 2006. Palaeogene Ostracoda (Crustacea) from the Wangerrip Group, Latrobe-1 bore, Otway Basin, Victoria, Australia. *Proceedings of the Royal Society of Victoria* 118 (1): 87–111. ISSN 0035-9211.

Palaeogene (latest Paleocene–earliest Eocene) marine ostracod assemblages from subsurface Wangerrip Group units in the Latrobe-1 bore, Otway Basin, southern Victoria, Australia, are described and discussed. Twenty three taxa from nine families are represented: two species are new, *Neobuntonia taylori* sp. nov. and ?*Tasmanocypris latrobensis* sp. nov.; seven species are confirmed; six are inconclusive and eight are under open nomenclature due to insufficient material. Most of the forms extend the range of genera or species.

Keywords. Palaeogene, Ostracoda, Wangerrip Group, Latrobe-1 bore, Otway Basin, Victoria, Australia, taxonomy, Paleocene-Eocene boundary, Rivernook, Princetown.

SEVERAL descriptions and analyses of ostracod faunas from Palaeogene surface sections of southeastern Australia have been published recently however this taxonomic study is the first to describe subsurface Otway Basin Palaeogene Ostracoda. The borehole section studied ranged from Late Paleocene, across the Paleocene/Eocene boundary and into Early Eocene with ostracod assemblages from three significant marine ingressions occurring through this interval: the Rivernook A, Rivernook and Princetown ingressions.

PREVIOUS OSTRACOD STUDIES

The Palaeogene Ostracoda of southeastern Australia received no attention until 1943 when Crespin's exhaustive study of Gippsland Basin bores listed the occurrences of 72 ostracod species of which 37 were from Oligocene strata although at the time she had dated them as Middle Miocene (Crespin 1943). Unfortunately many of her identifications were based on Recent species (in particular Brady 1866, 1880) that often relied on European taxa of similar appearance. She also identified species as conspecific with Miocene and younger faunas (Chapman 1914; Chapman, Crespin and Keble 1928) whose authors had also relied on Brady's work. This resulted in a large number of misidentifications (McKenzie 1981) and combined with her lack of illustrations or descriptions, greatly reduces its usefulness.

From 1943 to 1973 the region's Palaeogene ostracods were occasionally mentioned in wider ranging studies, as faunal lists or in synonymies (e.g. Hornibrook 1952; Nadeau 1955; Van Morkhoven 1962; McKenzie 1967, 1973; Benson 1972).

In 1974 McKenzie in discussing Cenozoic ostracods of southeastern Australia, included several Palaeogene strata with ostracod assemblages and their palaeoenvironments (McKenzie 1974). This was followed by his analysis of species distribution in the Australian Cenozoic in terms of biogeographic patterns (McKenzie 1978) and briefly in the Tethyan context (McKenzie 1983). His studies of borehole faunas from the Willunga Embayment, St. Vincents Basin (McKenzie 1979), though short, provided much needed data for taxonomic and biostratigraphic work. An important and clarifying revision of the Chapman/Crespin Mallee and Sorrento bores taxonomy followed (McKenzie 1981). The earlier Willunga Embayment study was succeeded by a related discussion on the use of ostracods as petroleum-potential indicators across the Eocene/Oligocene boundary (McKenzie and Guha 1987).

During the 1990s a number of studies greatly enhanced the knowledge of southeastern Australian Palaeogene ostracod assemblages, they were: the Eocene/Oligocene faunas from the Gull Rock Member of the Blanche Point Formation, St. Vincent Basin and Jan Juc Formation in the Otway Basin (McKenzie et al. 1991); the Eocene Browns Creek Clays of the Aire District, Otway Basin (Mc-

Kenzie et al. 1993); Oligocene/Miocene palaeobiogeography within basins in Victoria, South Australia and Tasmania (Neil 1995); the Late Eocene Blanche Point Formation, St. Vincent Basin of South Australia (Majoran 1995; Majoran 1996a); the Eocene/Oligocene boundary in the Chinaman's Gully Formation (Majoran 1996b); cytheropterine ostracods of the Port Willunga Formation (Majoran 1997) and, finally, the Late Paleocene fauna from the Pebble Point Formation, Otway Basin providing the oldest Tertiary ostracods for this region (Neil 1997).

There are no published studies of ostracods from the Dilwyn Formation or from any subsurface sections of the Otway Basin Palaeogene. Neil (1997) examined the Pember Mudstone from Kaladbro 2 and Mumbannar 1 bores but that material did not yield ostracods. Relevant micropalaeontological studies have been primarily foraminiferal and palynological (in particular Taylor 1964, 1965, 1967, 1971; McGowran 1965, 1970, 1989, 1991; McGowran et al. 1971, 1997; Harris 1971, 1993; Stover and Partridge 1973; Tickell et al. 1993).

LOCATION OF AND BACKGROUND TO THE PRESENT STUDY

The Latrobe-1 borehole is located on the coast of SW Victoria (Fig. 1), W of the town of Princetown and approximately 1.65 km NW of Point Ronald. Location details from the Geological Survey of Victoria borehole system (GEDIS) log are: Princetown (7520.4.2) 1:25,000 Topographic Map, easting 686501, northing 5714955, latitude 38.69424°, longitude 143.14447°. Structurally it is within the southeastern Otway Basin in the southeastern part of the Port Campbell Embayment.

Completed in 1963, the bore was sited close to the Wangerrip Group type section to target the unexposed interval between the Princetown Member and the Clifton Formation. It bottomed at 626 m, well into the underlying Cretaceous sediments and though coring was virtually continuous there are within the section considered a number of breaks (Table 1). Because of the quantity of core overall and its strategic position the bore has been of particular interest for defining and correlating the regional stratigraphy and is referred to in many reports and studies and particularly extensively in Wopfner and Douglas (1971) and Douglas and Ferguson (1976, 1988, 1993).

In spite of its apparent potential the bore's microfauna proved disappointing, with Ostracoda only found between 211 and 344.4 m. Foraminiferal numbers were also either greatly reduced or entirely absent in samples outside of this section (Taylor pers. comm. 1970). Some of this deficiency is due to paralic/transgressive/regressive depositional conditions of non deposition, disturbance to or removal of sediments and in periods of adverse environmental conditions such as stagnant or restricted circulation or disturbed salinity levels. Ostracods are absent in otherwise promising marine beds that contain foraminifera, the probable reason for this being the dissolution of ostracods in sulphuric acid generated from the breakdown of pyrites to copiapite and jarrosite (Taylor 1965), the survival of the foraminifera being possibly due to their thicker and more resilient tests. The unfavourable chemical conditions in situ are not all pervasive since excellently preserved specimens were present in limonitic samples indicating oxidising conditions. High specimen numbers did not necessarily equate with good preservational conditions as some of the relatively rich assemblages had fragile, corroded specimens (eg. 47A, 47B) whereas other samples with low counts contained superbly preserved material (eg. 45B, 54C, 58A)

Samples for this study were those on which Taylor (1964, 1965, 1971) based his foraminiferal work. This research also provides information on ostracod-bearing strata of this age in the region, data on subsurface ostracod for the Otway Basin, contributes to information on the range of species previously described from Eocene and younger horizons and providesadditionalfaunal data across the Paleocene/Eocene boundary.

STRATIGRAPHY

Below 30–60 m the Latrobe-1 bore intersects the Tertiary Heytesbury, Nirranda and Wangerrip groups then the Mesozoic Sherbrook and Otway groups, only the Wangerrip Group produced ostracods.

The relevant formation within the Wangerrip Group is the Dilwyn (Late Paleocene-Early Eocene), interpreted as a paralic sequence of transgressive-regressive cycles resulting in fluctuating marine to brackish estuarine conditions (Bock and Glenie 1965; Glenie 1971; Holdgate and Gallagher 2003). Taylor (Taylor 1971) analysed several foraminiferal assemblages including Latrobe-1 and concluded that the depositional environment was marginal marine with

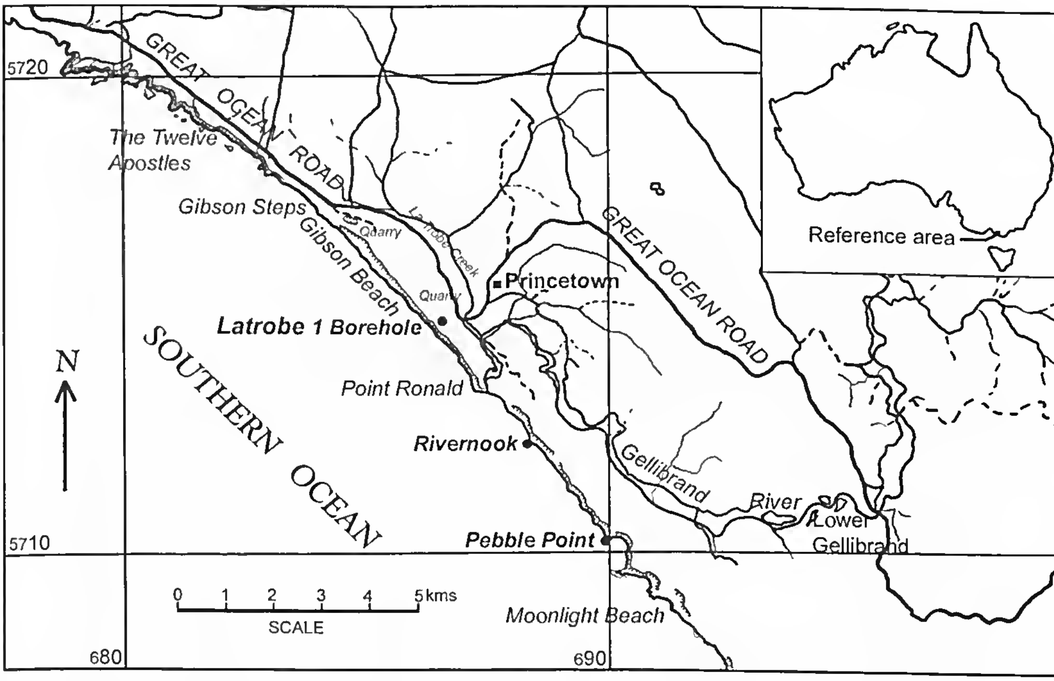

Fig. 1. Site of the Latrobe-1 Borehole near Princetown and neighbouring locations of Rivernook and Pebble Point, Otway Basin, Victoria.

sudden sporadic marine breakthroughs producing periodic rich marine faunas. The Dilwyn Formation is widespread subsurface and consists predominantly of quartz sand, often silty or clayey, sandy silt and clay, mudstone and shale. The finer grade sediments are commonly dark, carbonaceous, micaceous and pyritic. In this bore the formation was identified from a depth of 70.10–~345 m (GEDIS). Of the Dilwyn subunits, often restricted in occurrence, six are relevant to this study: the Princetown, Rivernook and Pember Mudstone members and the minor units, the *Trochocyathus*, *Turritella* and Rivernook A beds. The Princetown, Rivernook and Rivernook A strata are interpreted as ingressions, with each subunit containing its own distinctive faunal assemblage (McGowran 1965, 1970, 1991; Taylor 1964, 1965, 1971). The use of the names of the minor units has been retained to facilitate referral to these short stratigraphic intervals and to correlate them with Taylor's foraminiferal faunal units.

Taylor (Taylor 1964, 1965) had identified distinctive foraminiferal assemblages from both outcrop and subsurface. In his earlier report (Taylor 1964) he had named these the Princetown, *Trochocyathus*, Rivernook and Pebble Point faunas relating them to the stratigraphic units in which each "faunas" predominately occurred. He later replaced these faunal units with a system of lettered zonules for dating purposes (Taylor 1971), the reference section for these being Latrobe-1 with only very minor change in the depth positions for the zonules compared to the previous faunal positions (Taylor 1964). The zonules have had some degree of recognition and usage since however as they are chronostratigraphic units they are here unsuitable hence the reversion to Taylor's original faunal assemblages.

Though fauna is sparse in the outcropping Princetown Member at Princetown Taylor (1965) was able to correlate its characteristic foraminiferal assemblage in Latrobe-1 identifying the Princetown Member at 228.6 m and designating 207.26–256.03 m as Princetown Fauna. The *Trochocyathus* and *Turritella* beds are thin fossiliferous units first observed nearby in outcrop (Baker 1943, 1944, 1950). Taylor (1964) delineated 256.03–289.56 m as *Trochocyathus* Fauna but did not indicate the bed position within the bore section. Positions for these beds in the bore have not previously been indicated, the suggested positions have been derived from the faunal concentrations and by the beds' relative positions compared to the surface section (Taylor pers. comm. 1970). It is suggested that the *Turritella* Bed lies between ~262

Chronostratigraphy		Spore/pollen Zones (adapted from GEDIS; Harris 1971, 1993; Archer 1977; Fickell et al. 1993; Partridge pers. comms 2006)		Foram. Zones (McGowran 1991; Holdgate & Gallagher 2003)	Foraminiferal Faunas (Taylor 1964)	Proposed Positions of Stratigraphic Units	
Early Eocene	Ypresian	*Malvacipollis diversus* (undifferentiated)		P7	207.25 – 256.03 Princetown Fauna	WANGERRIP GROUP / DILWYN FORMATION	~70 – ~229.5 Princetown Member
					256.03 – 289.56 *Trochocyathus* Fauna		~257; *Troc.* Bed; DF; *Turr.* Bed; 264.5; 292
Earliest Eocene		Indeterminate	281.9				
Paleocene Eocene Boundary	PETM	Lower *M. diversus*	*S. prominatus* Subzone				
			296.9	P6b	289.56 – 305.4 Rivernook Fauna		Rivernook Mem
	Interval	*L. b.* – *M. d.* transition		P6a?			Riv. A
		314					
Late Paleocene	Thanetian	Upper *Lygistepollenites balmei*		P5	305.4 – 335.28 Pebble Point Fauna		Pember Mudstone Member

Latrobe-1 Borehole Lithology Based on GEDIS Logs

- Clay silt interbeded, shell frags
- Brown sand, carbonaceous, micq.
- Brown sand silt clayey silt
- Brown clayey silt, carbonaceous, mica, burrowed, shells
- Brown silt, carbonaceous, shells
- Shelly silt burrowed slightly.
- Brown sand, carbonaceous, micaceous, interbedded with fine grained silt, shell fragments, unbroken solitary corals, minor burrowing
- Sandstone, silty, carbon., shells.
- Brown silt, carbonaceous, mica grading to clayey silt, burrowed laminated at base, sparse shells
- Brown sandstone, carbonaceous silty, medium grained, minor gravel layers, sparse gastropods and shell fragments
- Brown sand, carbonaceous, med - course grained, sparse shell frags
- Silt, carbonaceous, mica grading to fine sand, rare shell frags, grading to fine grained sand
- Silt, carbon., grading to fine sand
- Silty clay, sparse shell fragments
- Brown silt, glauconitic, cemented
- **Rivernook A** 304.5 – 305.5
- Brown silt, carbon., mica, rare shells
- Brown carbon. silty clay
- Brown micaceous clayey silt, carbonaceous flecks, pyrite, mica
- Brown silt, carbonaceous, micaceous, burrowed, course sand-size pellets possibly glauconitic, pyrite, gravelly silt with gastropod casts

Core not recovered =

Sample Positions Depth in metres	Sample Number	*Trachyleberis careyi*	*Neobuntonia taylori* sp. nov.	*Paracypris* sp.	*Cytherella* sp. cf. *C. atypica*	*Cytherella* sp.	?*Tasmanocypris* sp.	?*T. latrobensis* sp. nov.	*Cytherelloidea jugifera*	*Trachyleberis thomsoni*?	*Kuiperiana* cf. *K. lindsayi*	?*Nestoleberis* sp.	*Cytherelloidea hyogea*?	*Cletocythereis kurrawa*	*Munseyella dunouna*	*Cytherella pinnata*	*Neonesidea* aff. *N. australis*	Indet. gen. sp.	*Cytheralison corrugata*?	*Cytheralison* sp.	*Echinocythereis karooma*	*Loxoconcha* sp.	?*Trachyleberis* sp.	*Cytherelloidea praeaurita*	*Total*	Foraminifera Present (X) (or other indications of marine environment)
207.25																										
211.23	40A	1			3			1								1	1				1		1		9	X
217.32	41A																								0	X
221.89	42A																								0	X
224.64	42B																								0	X
229.21	43B	7			6			5	4	4							3						1	3	33	X
242.32	44A																								0	X
245.06	44B					1		1																	2	X
254.2	45A																								0	X
257.84	45B	3			2					3											1				9	X
259-261	46 A B	4		1	4			1								2					3				15	X
262-265	47 A B, 860'	10			20			9	9	2						11	6	1	1	1	11	1			82	X
281.33	51A																									NFF
285.6	52A																									NFF
288.65	52B																								0	shell frags
289.56	52C																								0	shell frags
292.3	53B		2		7											1									10	X
296-7	54-C agg	4	3		38	1	1		4	2	1	1	1	1	2	8	1								68	X
298.9	54I-55 agg.				3	1		1	2																7	
305	56 agg				2	?	2																		5	X
308.46	56B																								0	X
309.37	56 bottom																								0	X
313.64	58A		1	?	1																				3	X
319.43	59A																								0	glauconite
329.64	61A	1																							1	X
334.37	62																								0	X
339.09	63A																								0	X
344.42	64															?									1	X
	Total	30	6	2	86	4	3	18	19	11	1	1	1	1	2	23	12	1	1	1	16	1	2	3	245	

Table 1. Distribution of early Palaeogene Ostracoda, chronostratigraphy and faunal units in Latrobe-1 borehole, aggregated samples are broken down in Table 2, (NFF = no fauna of any type found).

Foraminiferal Fauna Units (Taylor 1964)	Stratigraphic Units	Depth in metres	Sample Number	*Trachyleberis careyi*	*Neobuntonia taylori* sp. nov.	*Paracypris* sp.	*Cytherella* sp. cf. *C. atypica.*	*Cytherella* sp.	*?Tasmanocypris* sp.	*?T. latrobensis* sp. nov.	*Cytherelloidea jugifera*	*Trachyleberis thomsoni?*	*Kuiperiana* sp. cf. *K. lindsayi*	*?Xestoleberis* sp.	*Cytherelloidea hrycga?*	*Cletocythereis kurrawa*	*Munseyella dunoona*	*Cytherella pinnata*	*Neonesidea* aff. *N. australis*	Indet. gen. sp.	*Cytheralison corrugata?*	*Cytheralison* sp.	*Echinocythereis karooma*	*Loxoconcha* sp.	*Total*	Foraminifera (or other marine indicators)
	Dil. Fm.	254.20	45A																						0	X
Trochocyathus Fauna	*Troc.*	257.8	45B	3			2					3											1		9	X
	Dil. Fm	259.4	46A				1																		1	X
		260.60	46B	4		1	3			1								2					3		14	X
	Turr. Bed	262.1	860-2'				5											1							6	X
		262.7	47A	6			#			4	1	1						5	4					1	37	X
		264.6	47B	4						5	8	1						5	2	1	1	1	#		39	X
		288.40	48A																							NFF
	Dilwyn Fm.	289.56	52C																						0	molluscs
Rivernook Fauna		292.30	53B		2		7											1							10	X
	Rivernook Member	295.35	54	1	1		#												1						13	X
		-295.96	54 A	1	1		#	1			3	1			1	1	2	8							32	X
		-296.50	54 B	1			#		1		1		1	1											20	X
		-297.00	54 C	1	1							1													3	
		-297.50	54D																							NFF
		-298.00	54E																							NFF
		-298.50	54 F				3	1			1														5	X
		299.62	55							1	?														2	
		-302.00	55A																							trace
		-303.60	55B																							glauconite NFF
	Riv. A	304.80	56 top						2																2	X
		305.41	56A				2	?																	3	X
		308.5	56B																						0	X
		Total		#	5	1	#	3	3	#	#	7	1	1	1	1	2	#	7	1	1	1	#	1	196	

Table 2. Breakdown of distribution of ostracod species in Latrobe-1 bore from samples aggregated in Table 1, (NFF = no fauna of any type found).

and 264.5 m, the *Trochocyathus* Bed is intersected at 257.84 m and the Princetown Member between ~207 and ~229 m.

In Latrobe-1 the Pember Mudstone at the base of the Dilwyn Formation conformably overlies the Paleocene Pebble Point Formation, is almost 60 m in thick with its top generally recognised as at 288/289 m and the bottom 343.5/347 m (GEDIS logs) though the most likely position would appear to be just below the lowest occurrence of ostracods at 344.42 m. Near the base of the Mudstone are two thin units, Rivernook Member and Rivernook A.

The Rivernook Member outcrops in a coastal exposure of the Dilwyn Formation between Point Ronald and Moonlight Head where it consists of 6 m of glauconitic and limonitic sand and clay with a lower bed usually concealed by beach sand and referred to as Rivernook A also of glauconitic and micaceous silty clay (McGowran 1970; Abele, Kenley et al. 1993). In Latrobe-1 Taylor identified the Rivernook Fauna at 289.56–305.4 m (Taylor 1964, 1965) but did not indicate the stratigraphic interval for the Rivernook beds. He noted (Taylor pers. comm. 1970) a position for Rivernook A at 304.8 m. McGowran using his own and Taylor's earlier work described the identifying features of the foraminiferal fauna from Rivernook A (McGowran 1970). Based on the available information (including Taylor pers. comm.

1970) and the ostracod concentrations it is suggested that the Rivernook A Bed lies at approximately 304.5–305.5 m, probably grading directly into the overlying Rivernook Member which extends to ~292 m. Taylor's faunal units usually extend beyond the stratigraphic units of the same names, for instance Taylor in identifying the Pebble Point Fauna from 305.41–335.28 m noted that it ranged well above the Pebble Point Formation (Taylor 1964).

The importance of the Rivernook, Rivernook A and Princetown assemblages has been greatly enhanced with their being linked to the broader Australian palaeohistory, their names now applied to three ingressions regarded as significant marker events at or near the Paleocene/Eocene boundary (McGowran 1965, 1970, 1989, 1991; McGowran et al. 1997; Chaproniere, Shafik, Truswell, Macphail and Partridge 1996).

AGE

The top of the study section at 207.26 m is within the Stover and Partridge spore-pollen *Malvacippolis diversus* Zone, the base at 344.42 m is within the Upper *Lygistepollenites balmei* Zone, dated as Early Eocene and Late Paleocene respectively (Partridge and Dettmann 2003). Positions for spore/pollen zones and subzones (Table 1) were obtained from the Latrobe-1 bore logs and associated reports (GEDIS; Harris 1971, 1993; Archer 1977; Tickell et al. 1993; Stough in Partridge pers. comm. 2006; Partridge pers. comm. 2006).

The section spans the Paleocene-Eocene boundary, the exact placement of which is problematic. After this manuscript had been completed additional unpublished information from several sources became available that may upon further investigation clarify the boundary but it is beyond the scope of this predominately taxonomic study to give that data the in-depth consideration it warrants. The interval in question includes the *Spinizonocolpites prominatus* Subzone, the Upper *L. balmei*/Lower *M. diversus* boundary and the Rivernook A ingression and will be treated as a boundary interval of ?latest Paleocene/ ?earliest Eocene age. It is intended that the issue will be addressed in a future paper.

MATERIAL STUDIED

In 1970 David J. Taylor loaned the author 107 of his 250 Latrobe-1 residues used for his foraminiferal studies (Taylor 1964, 1965, 1971). Taylor collected and treated 200 gm samples, for this study these residues were re-sieved and picked with 21 of the 107 samples yielding ostracods. The productive samples were from the interval 211.23 m to 344.42 m (samples 40A — 64), though within this interval Taylor's sampling log (pers. comm. 1970) recorded numerous missing intervals of core not evident in the GEDIS log. Not all unproductive samples have been included in Table 1. Residue sizes varied from a few grams to up to 100 gm depending on the clay content removed in initial washing. When present, the ostracod frequency was usually very low. Many specimens were severely affected by acidic conditions *in situ* leaving surviving shells fragile, though by contrast some were in excellent condition. In the years subsequent to initial collection some specimens were lost or broken through transportation, storage problems and slide damage, reducing the already small numbers.

COMMENTS ON THE FAUNA

Due to such small numbers, a statistical analysis would be misleading. Faunal representation will be discussed both quantitatively and qualitatively but based on this material the former should be viewed as a guide to taxa represented.

In all there were nine families, 15 genera and 23 species with a total of 245 specimens. Two species are new, *Neobuntonia taylori* sp. nov. and ?*Tasmanocypris latrobensis* sp. nov.; seven species identifications are confirmed; six are inconclusive for reasons discussed and eight are under open nomenclature due to insufficient material. Most of the forms extend the range of genera or species. The families represented were:

- CYTHERELLIDAE: Two genera: *Cytherella*, 3 species; *Cytherelloidea*, 3 species.
- PARACYPRIDIDAE: Two genera: *Paracypris*, 1 species; ?*Tasmanocypris*, 2 species.
- BAIRDIIDAE: One genus: *Neonesidea*, 1 species.
- LOXOCONCHIDAE: Two genera: *Loxoconcha* and *Kuiperiana*, 1 species each.
- XESTOLEBERIDIDAE ?: Allocation tentative, 1 specimen.
- BYTHOCYTHERIDIDAE: One genus: *Cytheralison*, 2 species.
- PECTOCYTHERIDIDAE: One genus: *Munseyella*, 1 species.
- HEMICYTHERIDIDAE: One genus: *Neobuntonia*, 1 species.

- TRACHYLEBERIDIDAE: Three genera: *Trachyleberis*, 3 species; *Echinocythereis*, 1 species; *Cletocythereis*, 1 species; *incertae sedis*, 1 species.

Three species were found to be markedly smaller in size than those from other areas, they were *Neonesidea* aff. *N. australis*, *Trachyleberis thomsoni*? and *Cytherelloidea jugifera*, these may represent dwarf forms indicative of a population under environmental stress.

THE OSTRACOD ASSEMBLAGES.

The ostracod assemblages coincide with Taylor's foraminiferal faunas (Taylor 1964) and correspond to periods of ingression with more favourable marine conditions. Within these ingressions are intervals with no fauna of any type observed or with very low representation, whilst some may be due to poor preservation, others indicate periods of more adverse conditions and variability within the ingression events. The high sampling frequency provided a level of detail within these events not often available, a more detailed study of these with additional data is in preparation.

When the ostracod distribution is examined across Taylor's faunal units (Table 1) four distinctive horizons are evident with respect to specimen numbers and diversity, they are: in the Rivernook Fauna; the *Turritella* Bed within the *Turritella* Fauna and in the lowermost and uppermost sections of the Princetown Fauna. These ostracod horizons align with the higher foraminiferal concentrations (Taylor pers. comm. 1970).

Pebble Point Fauna. This was the least productive of the faunal units, three samples yielding 5 ostracod taxa of which three were long-ranging species, one a shorter ranging paracyprid, and the fifth a very short-ranging new species of *Neobuntonia*.

Rivernook Fauna. Abundance and diversity increases up section within the Rivernook strata, in all there are 15 taxa (90 specimens), 11 species appearing for the first time, six not found outside this faunal unit within the section. The prominent horizon at ~296–297 m contained 14 of the 15 taxa.

Trochocyathus Fauna. The lower part of this faunal unit has large sections of missing core, the remainder is quite devoid of ostracods and some samples have no observed fauna of any type. In the upper part of the unit ostracods were found only in the *Turritella* and *Trochocyathus* beds and the interval between them. The *Turritella* Bed is the most evident ostracod horizon in this faunal unit yielding 12 taxa, (82 specimens), from two samples. Five species appear for the first time, only one of these, *Echinocythereis karooma*, extends beyond the unit, the other four cannot be identified with certainty. Despite the high specimen yield the preservation of the specimens was generally poor. The more impoverished *Trochocyathus* Bed had four species, in all nine specimens but with a much better level of preservation, some specimens in pristine condition.

Princetown Fauna. Within this 50 m unit there are only three ostracod-bearing samples of which the 229.21 m horizon at or near the base of the Princetown Member is the most productive containing eight taxa, 33 well preserved specimens. The horizon at the top of the section has only 9 specimens from 7 taxa, none are new to this horizon, all except the unidentified ?*Trachyleberis* sp. are long-ranging within the section, four are found in younger strata elsewhere, they are *Trachyleberis careyi*, *Cytherella* sp. cf. *C. atypica*, *Cytherella pinnata* and *Echinocythereis karooma* (McKenzie et al. 1991, 1993; Eglington in prep). This horizon's prominence is enhanced by the absence of any ostracods above it.

TAXONOMY

The following conventions and abbreviations are used; C articulated carapace; LV left valve; RV right valve; F female; M male; juv. juvenile; A adult; A1 final stage instar; ~ approximate (depth). SEMs have all been reproportioned to correct for inherent software errors.

Order PODOCOPIDA Müller, 1894
Suborder PLATYCOPA Sars, 1866
Family CYTHERELLIDAE Sars, 1866
Cytherella Jones, 1849

Cytherella sp. cf. **C. atypica**
Bate, 1972
Figs 2G-N, P

Affinities.

Cytherella atypica Bate 1972: 4, 5, Pl. 3, figs 1–4, text figs 2A, 2B, 2D, 2F.

Cytherella sp. Whatley and Downing 1983: 385, Pl. 8, figs 6–8.

non *Cytherella* cf. *C. pinnata* — Neil 1997: 170, fig. 4C.

Remarks. Smooth, ovate cytherellid with left valve overlapping right and twin brood chambers in the female. This material fits the description of *C. atypica* Bate. 1972. the only hesitancy to unequivocal identification is due to a consistent feature at variance with *C. atypica* (as illustrated in Bate 1972, Text fig. 2D) in the anterior selvage of *C.* sp. cf. *C. atypica*. In *C.* sp. cf. *C. atypica* the outer rim of the anterior interior margin of the larger (left) valve is reduced and stepped down on the outermost edge rather than having the bulging lip present in the remainder of the marginal outer edge of the larger valve. The size range is consistent with *C. atypica.* Whatley and Downing (1983) regarded their *C.* sp. as not *C. atypica* due to their specimens being larger in size and having a "slightly umbonate dorsal margin". When comparing sizes and shape it was felt these were insufficiently divergent to be accorded separate species status. Size comparisons in millimetres are as follows:

Cytherella atypica Bate, 1972

A Fs, length, 0.79–0.85 mm, height, 0.5–0.59 mm.

A Ms, length, 0.81–0.83 mm, height, 0.51–0.56 mm.

Cytherella sp. Whatley and Downing, 1983

A Fs, length, 0.9–0.92 mm, height, 0.59–0.6 mm.

A Ms, length, 0.81 mm, height, 0.49 mm.

Cytherella sp. cf. *C. atypica*

A Fs, length, 0.75–0.975 mm, height, 0.53–0.6 mm.

A Ms, length, 0.7–0.875 mm, height, 0.525–0.61 mm.

Whereas *C.* sp. Whatley and Downing, 1983 has adult females larger than females of *C. atypica* Bate, 1972, the males of both are the same size. When the three forms are compared *C.* sp. cf. *C. atypica* spans the size-ranges of the other two. It is also possible that those identified as small adults are precocious final stage juveniles. As to the umbonate dorsal outline of *C. atypica* Bate, 1972, when outlines of specimens of *C.* sp. cf. *C. atypica* are examined some are more convex than others. These shape variations between the three populations may well be no more than a reflection of environmental or phylogenetic factors and some degree of intraspecific variation.

C. cf. *C. pinnata* of Neil (1997), shown in his figured specimen 4C right valve, has the stepped-down margin of the smaller valve; it could therefore be *C. atypica* or a close affinity.

C. sp. cf. *C. atypica* is the second longest ranging species in the section and by far the most numerous.

Measurements. RV F, length 0.8 mm, height 0.5 mm.

RV F, length 0.91 mm, height 0.6 mm.

RV M, length 0.98 mm, height 0.58 mm.

LV length 0.83 mm, height 0.55 mm.

LV M, length 0.6 mm, height 0.26 mm.

LV M, length 0.75 mm, height 0.54 mm.

CF, length 0.8 mm, height 0.5 mm, breadth 0.38 mm.

CF, length 0.75 mm, height 0.52 mm, breadth 0.4 mm.

Material. 82 adult and juvenile specimens plus fragments.

Figured Specimens. Figs 2G, I, N (NMV P 312757), sample 46B at 260.60 m; Figs 2H, M, P (NMV P 312758), sample 54 at 295.35 m; Fig. 2J (NMV P 312755), sample 54 at 295.35 m; Fig. 2K (NMV P 312756), sample 58A at 313.64 m; Fig. 2L (NMV P 312759) sample 43B at 229.21 m.

Location and Age. Latrobe-1 bore, Dilwyn Formation including Pember Mudstone from 313.64 — 211.23 m; Late Paleocene — Early Eocene.

Cytherella pinnata
McKenzie, Reyment and Reyment, 1993
Figs 2A-F

Cytherella pinnata McKenzie, Reyment and Reyment 1993: 78, pl. 1, figs 1, 2.

Cytherella cf. *C. pinnata* — Neil 1997: 170, fig. 9F.

Remarks. This Cytherellid was noted by its authors to have the normal cytherellid right-over-left overlap plus two brood chambers in the adult females. *C. pinnata* bears a close resemblance to *C. atypica* Bate, 1972 and to *C.* sp. cf. *C. atypica* of this paper in overall size, shape, appearance and in having twin brood pouches. However *C. atypica* has reversed overlap of left over right. Both species occur in this section, often in the same samples. As they are almost identical the only simple criterion for identifying them was the overlap. The distinctive adductor muscle scars in *C. pinnata* mentioned by its authors were not observed.

The right valve of *C.* sp. cf. *C. pinnata* of Neil (1997: 4C) has the reversed overlap seen in *C. atypica* and is therefore not *C. pinnata* which displays the normal R>LV overlap.

Measurements. Average F LV length 0.9–0.92 mm, height 0.5–0.55 mm.

Material. 23 specimens of adults and juveniles of both sexes.

Figured Specimens. Fig. 2A (NMV P 312750), sample 54A at ~ 295.96 m; Figs 2B, C (NMV P 312751), sample 47A at 262.74 m; Figs 2D, F (NMV P 312752), sample 54A at ~295.96 m; Fig. 2E (NMV P 312753), sample 47B at 264.57 m.

Location and Age. Latrobe-1 bore, Dilwyn Formation including Rivernook Member, ~295.96 — 211.23 m; ?latest Paleocene/?earliest Eocene — Early Eocene.

Cytherella sp.
Fig. 2O

Remarks. A moderate sized cytherellid, subrectangular in lateral view. Anterior margin semicircular; posterior margin broadly rounded in the two available adult females, longest medially. Ventral and dorsal margins slightly concave to slightly convex. Maximum height approximately midway between anterior margin and adductor muscle scars. Maximum breadth just behind the adductor muscle scars depression. RV overlaps LV. Surface overall smooth with fine reticulations observed along the anterior marginal area in the LV. Internally there are two posterior brood chambers. Adductor muscle scars midway along the length, in slight depression and angled diagonally; details could not be discerned.

These specimens do not display the anterior and posterior micropunctae of Early Miocene *C. paranitida* Whatley and Downing, 1983, or the postero-marginal ridge of Late Oligocene *C. bellsi* McKenzie, Reyment and Reyment, 1991 and *C.* sp. aff. *C. bellsi* McKenzie, Reyment and Reyment, 1993.

Measurements. FLV length 0.75 mm, height approx. 0.4 mm.

FRV length 0.7 mm, height approx. 0.45 mm.

Material. Two valves, both adult females; two others lost in storage.

Figured Specimen. Fig. 2O (NMV P 312754), sample 54A at ~295.96 m.

Location and Age. Latrobe-1 bore, Dilwyn Formation including Rivernook Member, ?305.41 — ~295.96 m; ?latest Paleocene/?earliest Eocene — Early Eocene.

Cytherelloidea Alexander, 1929

Cytherelloidea jugifera
McKenzie, Reyment and Reyment, 1991
Figs 3A-B

Cytherelloidea sp. McKenzie 1979: 96, pl. 1, fig. 7.
Cytherelloidea jugifera McKenzie, Reyment and Reyment 1991: 139–140, pl. 1, figs. 10–12.
Cytherelloidea jugifera — McKenzie, Reyment and Reyment 1993: 79.
Cytherelloidea jugifera — Majoran 1995: Fig. 3F, app. ta.
Cytherelloidea jugifera — Majoran 1996: 20, 21, 22, 24, pl. 1, fig. 2, text fig. 6, ta. 1, apps. 1, 2.

Remarks. Adults from this location were smaller than the Late Eocene specimens but otherwise conformed.

Measurements. RV F, length 0.875 mm, height 0.54 mm.

C F, length 0.83 mm, height 0.5 mm, breadth, 0.375 mm.

LV juv, length 0.7 mm, height 0.45 mm.

Material. Eighteen specimens including one carapace, mostly juveniles.

Figured Specimens. Fig. 3A (NMV P 312761); Fig. 3B (NMV P 312762). Both from sample 54A at ~295.96 m.

Location and Age. Latrobe-1 bore, Dilwyn Formation including Rivernook Member, ?299.62 — 229.21 m; ?latest Paleocene/?earliest Eocene — Early Eocene.

Cytherelloidea hrycega?
McKenzie, Reyment and Reyment, 1993
Figs 3C-D

Affinity.
Cytherelloidea hrycega McKenzie, Reyment and Reyment 1993: 79, pl. 1, figs 7–9.

Remarks. This one juvenile was dissimilar to juveniles of *C. jugifera* McKenzie Reyment and Reyment,

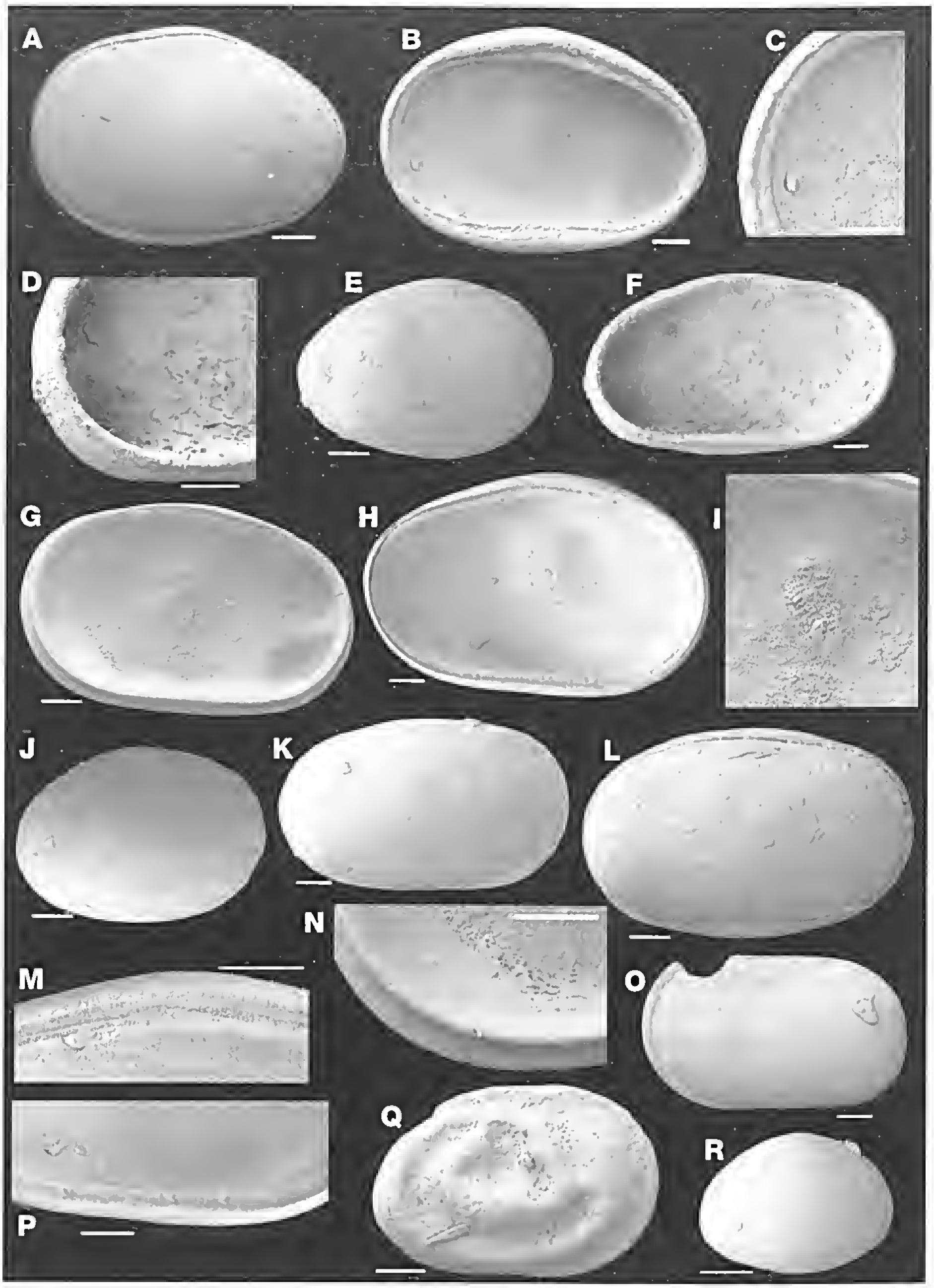

Fig. 2. A-F, *Cytherella pinnata*. A, P312750 adult carapace LV. B, P312751 adult female RV internal. C, P312751 detail of margin RV internal. D, P312752 detail of margin LV internal. E, P312753 juvenile RV external. F, P312752 adult female LV internal. G-N, *Cytherella* sp. cf. *C. atypica*. G, P312757 adult female RV internal. H, P312758 adult male LV internal. I, P312757 adductor muscle scars RV internal. J, P312755 juvenile RV external. K, P312756 adult RV external. L, P312759 adult female carapace RV. M, P312758 details of margin LV internal. N, P312757 details of margin RV internal. O, *Cytherella* sp. P312754 adult, female, LV. P, *Cytherella* sp. cf. *C. atypica* P312758 details of margin LV internal. Q, *Cytherelloidea praeauricula* P312763 adult female RV. R, ? *Xestoleberis* sp. P312760 carapace LV external.

Scale bar = 100 microns (1/10 mm.) except for C, D, I, M, N, P in which scale bar = 10 microns (1/100 mm.). All illustrations have been re-proportioned to correct for standard software errors.

1991 with the ventral ridge of *C. hrycga*? being narrower, less pronounced and much closer to the posterior margin.

Measurements. LV juv., length 0.8 mm, height 0.46 mm.

Material. One juvenile LV.

Figured Specimen. Figs 3C-D (NMV P 312790) from sample 54A at ~295.96 m.

Location and Age. Latrobe-1 bore, Dilwyn Formation, Rivernook Member, ~295.96 m; ?latest Paleocene/?earliest Eocene.

Cytherelloidea praeauricula
(Chapman, 1926)
Fig. 2Q

Cytherella praeauricula Chapman 1926: 105–106, pl. 22, fig. 9.
Cytherella praeauricula — Hornibrook 1952: 24.
Cytherelloidea praeauricula — Swanson 1969: 38, pl. 1, figs 14–16.
Cytherelloidea praeauricula — Ayress 1995: 900, 913, ta. 1, figs 12.8–9.

Remarks. This location is the source of the first Australian record of this species; it predates the New Zealand occurrences of Late Eocene (Ayress 1995) to Early Miocene age (Swanson 1969). The small size and distinctive ridging compares well to the illustrations of both Ayress and Swanson as well as to Australian specimens from Browns Creek, Castle Cove, Duck Creek and Narrawaturk 2 (Eglington in prep.). The short anterior/median ridge connecting the outer and inner concentric ridges is less conspicuous in these earlier Latrobe specimens than in those from the other locations listed and may reflect an earlier evolutionary stage in the development of this feature.

Measurements. RV F length 0.63 mm, height 0.40 mm.
LV length 0.60 mm, height 0.37 mm.
LV. length 0.55 mm, height 0.28 mm.

Material. Three specimens: one right valve female displaying twin brood pouches, one left valve and one smaller left valve (presumed to be A1 instar).

Figured Specimen. Fig. 2Q (NMV P 312763) from sample 43B at 229.21 m.

Location and Age. Latrobe-1 bore, Dilwyn Formation, Princetown Member, 229.21 m; Early Eocene.

Suborder PODOCOPA Sars, 1866
Family PARACYPRIDIDAE Sars, 1923
Paracypris Sars, 1866

Paracypris sp.
Figs 3E-F

Remarks. This identification is based on the sub-triangular valve shape with maximum height anteriorly. Muscle scars appear to conform to the paracyprid type (Maddocks 1988) but were very indistinct. Hinge adont. Inner margin and line of concrescence do not coincide.

Measurements. Length approx. 0.8 mm, height 0.41 mm.

Material. One broken left valve. Another possible specimen of this species was found at 329.64 m in Pember Mudstone but lost in storage, its identification is based on a sketch.

Figured Specimen. Figs 3E-F (NMV P 312767) from sample 46B at 260.6 m.

Location and Age. Latrobe-1, Dilwyn Formation, 260.6 m; Late Paleocene? — Early Eocene.

Tasmanocypris McKenzie, 1979

?**Tasmanocypris latrobensis** sp. nov.
Figs 3G-I

Derivation. Named after the location from which it has been described.

Types. Holotype is the specimen NMV P 312766 'Fig. 3I' from the Dilwyn Formation at 260.60 m depth (46B). Paratypes are: NMV P 312764 'Fig. 3G' from the Dilwyn Formation at 264.57 m (47B) and NMV P 312765 'Fig. 3H' from 229.21 m (43B).

Diagnosis. ?*Tasmanocypris* with acutely angled posterior termination in left valve, subacuminate in RV, dorsum arch angled.

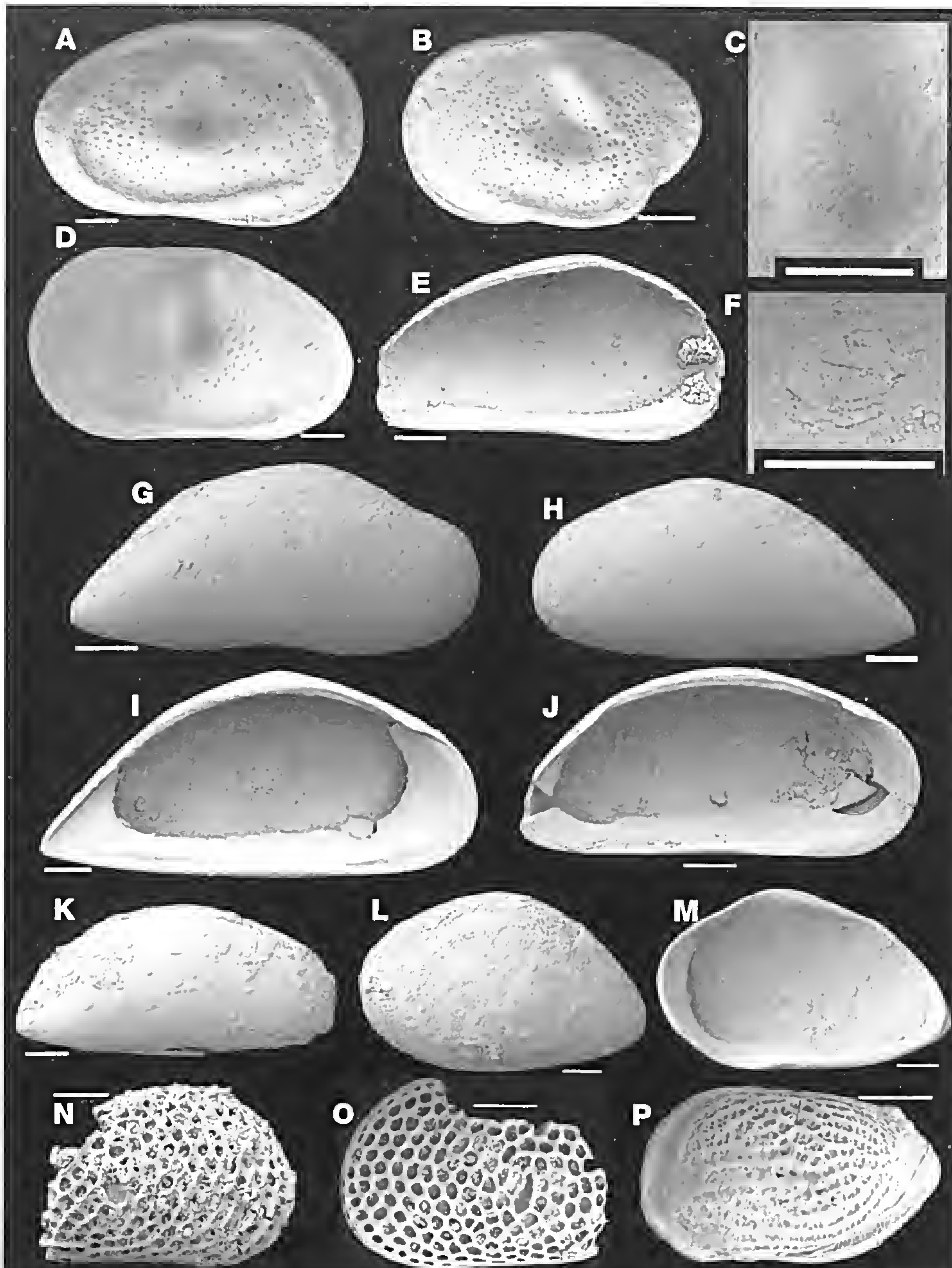

Fig. 3. A-B, *Cytherelloidea jugifera*. A, P312761 adult carapace RV. R, P312762 juvenile LV. B, P312762 juvenile LV. C-D, *Cytherelloidea bryega*? C, Detail of adductor muscle scars external. D, P312790 juvenile LV external. E-F, *Paracypris* sp. E, P312767 damaged LV internal. F, P312767 LV internal adductor muscle scars. G-I, ?*Tasmanocypris latrobensis* sp. nov. G, P312764 adult RV external. H, P312765 adult LV external. I, P312766 adult LV internal. J-K, ?*Tasmanocypris* sp. J, P312769 LV internal. K, P312768 carapace RV external. L-M, *Neonesidea* aff. *N. australis*. L, P312770 adult carapace LV. M, P312771 adult RV internal. N, *Cytheralison corrugata*? P312775 fragment RV, external. O, Cytheralison sp. P312778 fragment LV. P, *Kuiperiana* sp. cf. *K. lindsayi* P312773 adult carapace LV.

Scale bar = 100 microns (1/10 mm.) except for C, F in which scale bar = 10 microns (1/100 mm.). All illustrations have been re-proportioned to correct for standard software errors.

Description. Smooth shelled paracypridid, subtriangular in lateral view with broadly rounded anterior margin and angular to subacuminate posterior termination. Outline of the left larger valve straight to convex on all margins except the sometimes slightly concave venter. RV concave antero-dorsally, rising to angular arched dorsum then descending in straight line from postero-dorsal angle to acutely angled posterior. Maximum height and breadth medial or slightly anterior of the medial line; maximum length close to the ventral margin. Internally the inner margin and line of concrescence do not coincide, with wide vestibules in anterior and posterior areas.

Remarks. Assigned to ?*Tasmanocypris* on the size, general shape, maximum height medially, LV larger than RV, central muscle scars arrangement, and large vestibules. The muscle scar pattern is that of *Tasmanocypris* and not of *Phlyctenophora*. *Paracypris* (emended diagnosis Maddocks 1988) is far less symmetrical in lateral and dorsal view with maximum height and breadth well forward of the medial line. Despite the common ancestry and close relationships between these and other genera (McKenzie 1982), there remains much confusion within the family, particularly since most diagnoses were made on soft parts of Recent material and not on fossils (Maddocks 1988). McKenzie's original description of *Tasmanocypris* was based on one Recent species, *T. dartnalli* McKenzie, 1979. Another Recent species was added later, *T. dietmarkeyseri* (Hartmann 1979). Both of these species have rounded posterior margins. The later inclusion of *T. eurylamella* McKenzie, Reyment and Reyment introduced a species with a more angled posterior, closer in appearance to ?*T. latrobensis* than the younger material. This species was most prolific in the stratum believed to be the *Turritella* Bed.

Measurements. Length ranges from. 0.93–1.3 mm, height 0.4–0.5 mm, except for smaller specimens from 47A of length 0.78 and 0.4 mm which appear to be the same species.

Material. 18 carapaces and valves plus fragments, all adult.

Location and Age. Latrobe-1, Dilwyn Formation including Rivernook Member, 299.6 m–211.23 m; ?latest Paleocene/?earliest Eocene — Early Eocene.

?**Tasmanocypris** sp.
Figs 3J-K; 5L-M

Remarks. Tentative tasmanocyprid identification in preference to *Paracypris* (emended diagnosis Maddocks 1988) based on proportions (maximum height and breadth are medial or very close to medial), left valve overlap, adductor muscle scar pattern of two subvertical rows (3 anterior scars, 2 posterior plus long capping scar) and wide inner lamella with wide vestibule.

Measurements. LV (broken), length approx. 0.85 mm, height 0.4 mm.

C, length 0.8 mm, height 0.42 mm, breadth 0.4 mm.

C (damaged) length 0.86 mm, height 0.4 mm.

Material. 2 carapaces and 1 valve.

Figured Specimens. Fig. 3J, 5L-M (NMV P 312769) from sample 54B at ~296.5 m; Fig. 3K (NMV P 312768) from sample 56 Top at 304.8 m.

Location and Age. Latrobe-1, Dilwyn Formation, Rivernook Member and Rivernook A Bed, 304.8–~296.5 m; ?latest Paleocene/?earliest Eocene.

Suborder PODOCOPA Sars, 1866
Family BAIRDIIDAE Sars, 1888
Neonesidea Maddocks, 1968

Neonesidea aff. **N. australis**
(Chapman, 1914)
Figs 3L-M

Affinities.

Bairdia australis Chapman 1914: 31–32, pl. 6, fig. 7.

Nesidea ovata (Bosquet, 1853); Tressler 1954, 433.

Neonesidia [sic.] *australis* — Whatley and Downing 1983: 351, pl. 1, figs 5–6.

Neonesidea australis — Warne 1987: 441.

Neonesidea australis — Warne 1988: 16, figs 9A-B.

Neonesidea australis — McKenzie, Reyment and Reyment 1991: 140, pl. 1, fig. 5.

Neonesidea australis — Ayress 1995: fig 4.1, tas 1, 3.

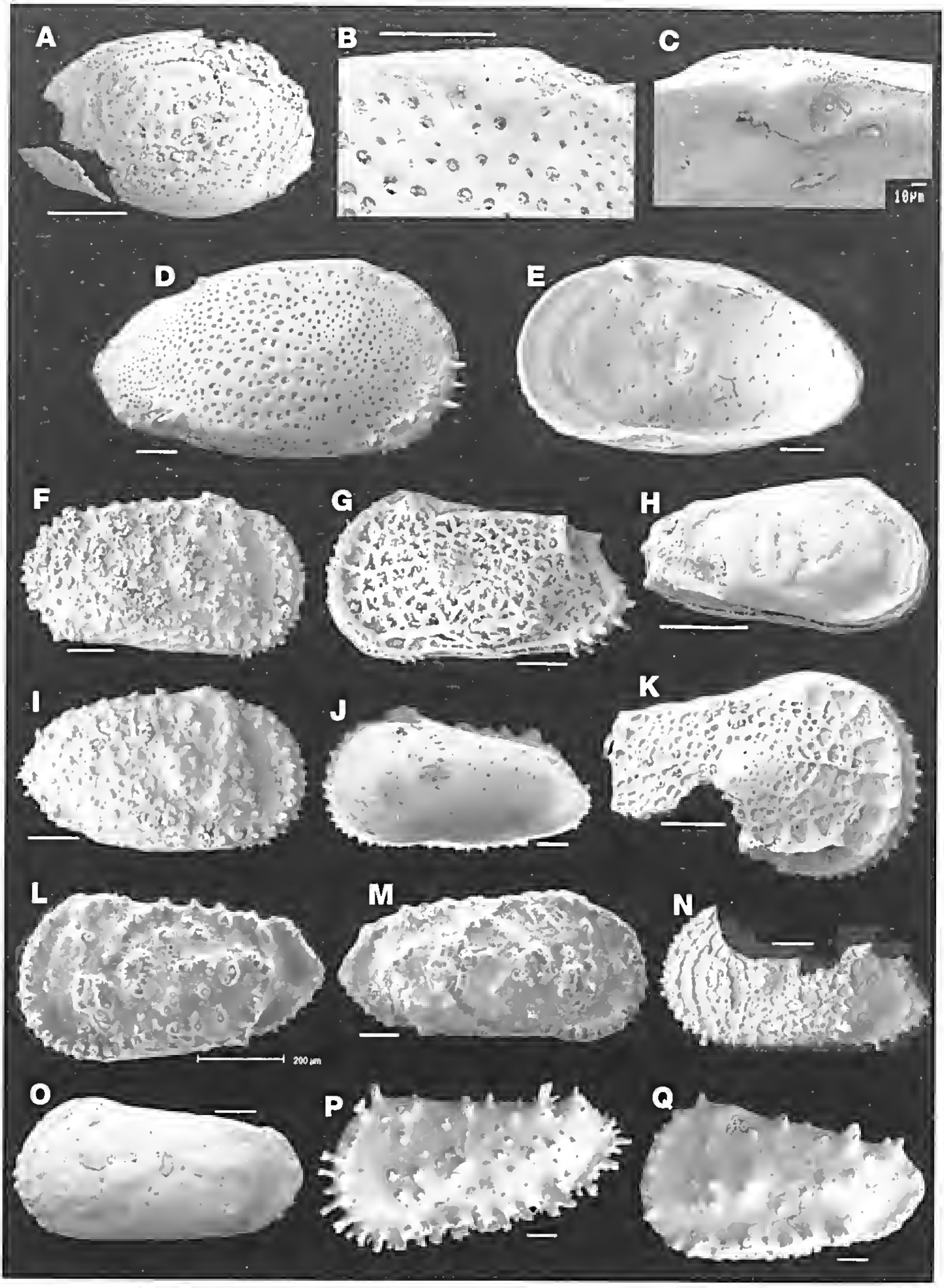

Fig. 4. A, *Loxoconcha* sp. P312772 damaged LV. B-E, *Neobuntonia taylori* sp. nov. B, P312774 RV external detail of "hinge ear" area. C, P312777 RV internal detail anterior hinge element and possible ocular sinus. D, P312774 adult RV external. E, P312777 adult RV internal. F, *Echinocythereis karooma* P312779 adult male RV. G, *Cletocythereis kurrawa* P312781 adult carapace LV. H, *Munseyella dunoona* P312780 carapace RV, external. I, *Echinocythereis karooma* P312776 adult female RV. J, *Trachyleberis careyi* P312787 adult RV internal. K, Indet. gen. sp. P312782 fragment RV. L-M, *Trachyleberis thomsoni*? L, P312784 adult female LV external. M, P312785 adult male RV external. N, *Trachyleberis careyi* P312788 damaged juvenile LV external. O, ?Trachyleberis sp. P312783 adult LV external. P-Q, *Trachyleberis careyi*. P, P312789 adult LV external. Q, P312786 adult LV external.

Scale bar = 100 microns (1/10 mm.) except for B-C in which scale bar = 10 microns (1/100 mm.). All illustrations have been re-proportioned to correct for standard software errors.

Remarks. This species is very similar in outline to *N. australis* (Chapman, 1914) especially when compared to *N. australis* of Ayress (1995). Internally the inner margin of *N. australis* in Whatley and Downing, (1983) appears to be narrower than *N.* aff. *N. australis*, particularly posteriorly. The most significant difference is size; this form is considerably smaller than others recorded ranging in length from 1.2–1.25 mm (Whatley and Downing 1983; Warne 1988; McKenzie, Reyment and Reyment 1991). *N.* aff. *N. australis* is presumably an ancestor of *N. australis*. If confirmed as the same species this would extend its range from the previously earliest appearance, Late Oligocene (McKenzie, Reyment and Reyment 1991) back to earliest Eocene and possibly Late Paleocene. The fragment from 344.42 m has the characteristic muscle scars of the genus.

Measurements. Length 0.82–0.85 mm, height 0.47–0.58 mm.

Material. Eleven mostly damaged specimens, both sexes.

Figured Specimens. Fig. 3L (NMV P 312770); Fig. 3M (NMV P 312771). Both from sample 43B at 229.21 m.

Location and Age. Latrobe-1, Dilwyn Formation including Rivernook Member and possibly Pember Mudstone, 295.35–211.23 m, possibly also 344.42 m; ?latest Paleocene/?earliest Eocene — Early Eocene.

Family LOXOCONCHIDAE Sars, 1925
Kuiperiana Bassiouni, 1962

Kuiperiana sp. cf. **K. lindsayi**
McKenzie, Reyment and Reyment, 1991
Fig. 3P

Affinities.
Myrena sp. McKenzie 1979: 93, 94, pl. 1, fig. 10, p. 100, Fig. 2.
Myrena lindsayi McKenzie, Reyment & Reyment 1991: 152, pl. 4, fig. 4, pl. 5, fig. 10.
Myrena lindsayi — McKenzie, Reyment & Reyment 1993: 89, pl. 3, figs 4–7.
Kuiperiana lindsayi — Majoran 1995: fig. 3U, app. ta.
Kuiperiana cf. *lindsayi* — Ayress 1995: tas. 1,3, fig. 8.2.
Kuiperiana lindsayi — Majoran 1996: 22, pl. 1, fig. 3.

Remarks. Kuiperiana is a senior synonym of *Myrena* Neale, 1967 (Szczechura 2001). More reticulate than type description and with more pronounced caudal process.

Measurements. Length 0.42 mm, height 0.25 mm, breadth 0.20 mm.

Material. One carapace.

Figured Specimen. Fig. 3P (NMV P 312773) from sample 54B at ~296.5 m.

Location and Age. Latrobe-1 bore, Pember Mudstone, Rivernook Member, ~296,5 m; ?latest Paleocene/?earliest Eocene.

Family LOXOCONCHIDAE Sars, 1925
Loxoconcha Sars, 1866

Loxoconcha sp.
Fig. 4A

Loxoconcha sp. McKenzie, Reyment & Reyment 1991: 152, pl. 5, fig. 3.
Loxoconcha sp. McKenzie, Reyment & Reyment 1993: 89, pl. 3, fig. 8.

Remarks. Only one left valve fragment, possibly female, was found. Its similarity to *Loxoconcha* sp. McKenzie, Reyment and Reyment, 1993 is more readily apparent than to *Loxoconcha* sp. McKenzie, Reyment and Reyment, 1991, identified as being conspecific. The concentric ornament consists of broad, shallow pits and low murae.

Measurements. Approximate length 0.40 mm, approximate height 0.25 mm.

Material. One fragile left valve, possibly female, broken in handling.

Figured Specimen. Fig. 4A (NMV P 312772) from sample 47A at 262.74 m.

Location and Age. Latrobe-1 bore, Dilwyn Formation, *Turritella* Bed, 262.74 m; Early Eocene.

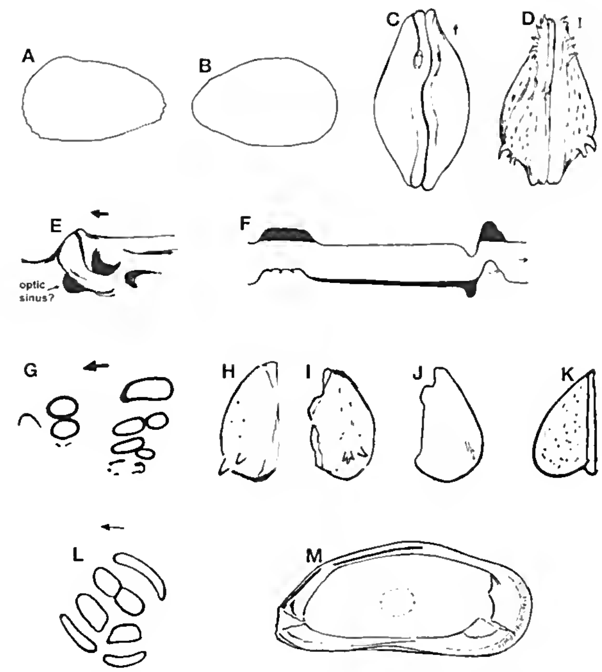

Fig. 5. A-J, *Neobuntonia taylori* sp. nov. A-B, Lateral view L and RV. C, P312774 and P312791, carapace dorsal view prior to opening. D, P312774 and P312791, carapace ventral view prior to opening. E, RV internal, anterior hinge element and possible optic sinus. F, P312774, P312791 hinge elements. G, Central muscle scars. H-J, Posterior views. H-I, P312774, P312791. J, RV. K, *N. batesfordiense* (Chapman 1910) posterior view. L-M, ?*Tasmanocypris* sp. P312769. L, Adductor muscle scars. M, P312769 LV internal view.

Family XESTOLEBERIDIDAE Sars, 1928
Xestoleberis Sars, 1866

?**Xestoleberis** sp.
Fig. 2R

Remarks. No taxonomically identifying features could be observed on this single carapace. The dorsal view is ovate with maximum width just post-medial. Left valve overlaps right. The surface is smooth and unornamented. Normal pore canals are large and evenly spaced. No muscle scars or xestoleberid spot observed. Identification based on the overall size, shape and overlap.

Measurements. Length 0.41 mm, height 0.26 mm, breadth 0.27 mm.

Material. One carapace.

Figured Specimen. Fig. 2R (NMV P 312760) from sample 54B at ~296.5 m.

Location and Age. Latrobe-1 bore, Dilwyn Formation, Rivernook Member, ~296.5m; ?latest Paleocene/?earliest Eocene.

Family BYTHOCYTHERIDAE Sars, 1926
Cytheralison Hornibrook, 1952

Cytheralison corrugata?
McKenzie, Reyment & Reyment, 1991
Fig. 3N

Affinity.
Cytheralison corrugata McKenzie, Reyment & Reyment 1991: 149–150, pl. 2, figs 11, 15, pl. 3, fig. 15.

Remarks. The single fragment resembles *C. corrugata* McKenzie, Reyment and Reyment, 1991. This and *Cytheralison* sp. extend the range for the genus in southeastern Australia to Early Eocene, predating the Late Eocene occurrence in the Browns Creek Clays at Castle Cove (McKenzie, Reyment and Reyment

1993). In Western Australia the genus is found in the Cretaceous of the Carnarvon Basin Bate (1972).

Measurements. Height 0.36 mm.

Material. One fragment, right valve.

Figured Specimen. Fig. 3N (NMV P 312775) from sample 47B at 264.57 m.

Location and Age. Latrobe-1 bore, Dilwyn Formation, *Turritella* Bed, 264.57 m; Early Eocene.

Cytheralison sp.
Fig. 3O

Remarks. This single *Cytheralison* fragment with its symmetry of concentrically arranged rounded pits matches none yet described.

Measurements. Height 0.35 mm.

Material. One left valve fragment.

Figured Specimen. Fig. 3O (NMV P 312778) from sample 47B at 264.57 m.

Location and Age. Latrobe-1 bore, Dilwyn Formation, *Turritella* Bed, 264.57 m; Early Eocene.

Family PECTOCYTHERIDAE Hanai, 1957
Munseyella Van Den Bold, 1957

Munseyella dunoona
McKenzie, Reyment & Reyment, 1993
Fig. 4H

Munseyella dunoona McKenzie, Reyment & Reyment 1993: 96, pl. 4, figs 7–10.
Munseyella dunoona — Majoran 1995: 77, Fig. 3L, Appendix Ta.
Munseyella dunoona — Ayress 1995: Tas 1, 3, Figs 8.10, 8.11.
Munseyella dunoona — Majoran 1996: Ta. 2, Appendices 1, 2.
Munseyella dunoona — Neil 1997: 174, Figs 2H, I.

Remarks. This specimen's identity was confirmed when compared to specimens of *M. dunoona* from the Rivernook Member outcrop (Eglington in preparation) despite the damage to its carapace

Measurements. Length 0.35 mm, height 0.20 mm, breadth, 0.16 mm.

Length 0.36 mm, height 0.20 mm, breadth mm, 0.16 mm (lost).

Material. Two carapaces, (one lost).

Figured Specimen. Fig. 4H (NMV P 312780) from sample 54A at ~295.96 m.

Location and Age. Latrobe-1 bore, Dilwyn Formation, Rivernook Member, ~295.96 m; ?latest Paleocene/?earliest Eocene.

Family HEMICYTHERIDAE Puri, 1953
Neobuntonia Hartmann, 1981

Neobuntonia taylori sp. nov.
Figs 4B-E; 5A-J

Derivation. Named after David J. Taylor, micropalaeontologist, who loaned the author the Latrobe-1 material in which this species was found.

Types. Holotype is an opened carapace (Figs 5C-D drawn prior to opening) with the right valve NMV P 312774 being Figs 4B, 4D, (the left valve NMV P 312791 is not illustrated) from the Pember Mudstone at 313.64 m (58A). Paratype: NMV P312777 'Fig. 4E' from the upper part of the Rivernook Member 292.3 m (53B).

Diagnosis. A neobuntonid with maximum length medially, maximum height at hinge ear, caudal process postero-medially positioned, and ornament of punctae that are coarsest in the subcentral area.

Description. The carapace is subovate in lateral view with broadly rounded anterior, dorsum and ventrum convex, posterior margin subrounded in right valve and in left valve sometimes slightly pointed. It is not expressed as a distinct caudal process. Maximum length medial, maximum height at hinge ear and maximum width just posterior of mid-length. Carapaces subequal with left valve overlapping right, but with anterior end of the right valve extending slightly past the left valve. When viewed dorsally the margin

is sinuous with the anterior dorsal area corresponding with the anterior hinge elements markedly intruding upon the right valve. In the medial area of the hinge this encroachment is temporarily reversed (Fig. 5C). This species has a ventral longitudinal ridge corresponding to the alar position; the carapace in sample 58A possessed sharp spines at the posterior termination of this ridge and in its vicinity (Fig. 5D). The anterodorsal hinge ear is more pronounced in the left valve with a large hemispherical surface expression somewhat resembling the appearance of an eye tubercle but is the reflection of the size and depth of the socket for the large anterior hinge element on the right valve. The right valve is not so developed in this hinge ear area. Ornament consists of a network of broad pits of various sizes that are larger in the central area and diminish in size anteriorly and posteriorly. The broad flat murae between the pits form a sub-concentric pattern with the most noticeable alignment being roughly parallel to the dorsal and ventral margins. Anterior and posterior marginal denticles are often present. Internally, the ventral margin is inflexed on both valves. The hinge (Figs 4C, E, 5F) is amphidont. The right valve anterior element is stepped. On the left valve the anterior element is smooth and the bar smooth or possibly very finely crenulate. Right valve rear hinge element is long, narrow and faintly lobed. Inner margin moderately wide, vestibule lacking. Beneath the right valve anterior hinge element is a small cavity which may be an optic sinus though a corresponding eyespot was not observed (Figs 4C, 5E). Central muscle scars in shallow depression, difficult to discern but appearing to conform to Neil's (1994) emended diagnosis for the genus as a subvertical row of four elongate adductors. Marginal pore canals difficult to discern but appearing to be simple, straight to slightly curved, more numerous in anterior margin than in posterior. Posterior marginal pore canals more concentrated in posteroventral sector. Normal pores large and evenly spaced.

Remarks. When compared with the only other similar species, *N. batesfordiense* (Chapman 1910), at Museum Victoria (NMV: P134964, P123366, P123367) *N. taylori* proved to be larger, differently shaped posteriorly and with differing pattern of the murae/pits. In comparison with figured specimens the following details were noted:

- The posterior view of *N batesfordiense* (Chapman 1910), p. 45, Pl. 8, fig. 36 "end view" redrawn this paper Fig. 5K differs from *N. taylori* (Figs 5H-J).
- The caudal process of *N. taylori* is somewhat at variance with *N. batesfordiense* (Chapman 1910), *N. siebertorum* Hartmann, 1981 (= synonymy of *N. batesfordiense*) and *N. batesfordiense* in Neil (1994).
- None of the above authors mention or illustrate spines in the vicinity of the ventral ridge, *N. taylori* possesses these in the specimen from 58A but not in 53A, however there can be considerable intraspecific variation in spinosity (Neil 1994).

Hartmann (1981) found *N. siebertorum* (synonym of *N. batesfordiense*) to be shallow marine on a coral reef in pools of higher than normal salinity. In the Latrobe samples the glauconite and sulphides suggest a different environment for this neobuntonid, one of normal salinity from 20–200 m depth with restricted circulation resulting in reducing conditions. The specimens could have been transported *post mortem* into such an area, but the pristine state of the spines on *N. taylori* from 313.64 m and the restricted circulation of such an environment would suggest that specimen at least is autochthonous.

This species appears to have been very short ranging, so far only being found in the Rivernook Member and one specimen ~15 m lower in the Pember Mudstone.

Measurements. RV, length 0.82 mm, height 0.46 mm.

RV, length 0.73 mm, height 0.45 mm.

C, length 0.95 mm, height 0.51 mm, width 0.5 mm.

LV, length 0.88 mm, height 0.45 mm.

Material. Six specimens plus several fragments. A single carapace from 313.64 m was opened after preliminary observations and the right valve scanned.

Location and Age. Latrobe-1 bore, Dilwyn Formation, Pember Mudstone and Rivernook Member, 313.64 — 292.3 m; Late Paleocene — ?latest Paleocene/?earliest Eocene.

Family TRACHYLEBERIDIDAE Sylvester-Bradley, 1948
Sub-family OERTLIELLINAE Liebau, 1975
Cletocythereis Swain, 1963

Cletocythereis kurrawa
McKenzie, Reyment and Reyment, 1993
Fig. 4G

Cletocythereis kurrawa McKenzie, Reyment and Reyment 1993: 111, pl. 7, figs 1–2.

Remarks. In their synonymy McKenzie, Reyment and Reyment (1993) list the 1979 citation of *Cletocythereis* sp. McKenzie, Pl. 2 figs 4,5. The authors had previously listed this species as *Cletocythereis* cf. *rastromarginata* not as *Cletocythereis kurrawa*. *C.* cf. *C. rastromarginata* is more appropriate.

This occurrence extends the range of *Cletocythereis kurrawa* in southeastern Australia to earlier than McKenzie, Reyment and Reyment's (1993) Late Eocene.

Measurements. Length 0.60 mm, height 0.35 mm, breadth 0.275 mm.

Material. One carapace, (scanned), one left valve lost from same sample.

Figured Specimen. Fig. 4G (NMV P 312781) from sample 54A at ~295.96 m.

Location and Age. Latrobe-1 bore, Dilwyn Formation, Rivernook Member, ~295.96 m; ?latest Paleocene/?earliest Eocene.

Sub-family ECHINOCYTHEREIDINAE Hazel, 1967
Echinocythereis Puri, 1954

Echinocythereis karooma
McKenzie, Reyment and Reyment, 1993
Figs 4F, I

Echinocythereis karooma McKenzie, Reyment and Reyment 1993: 112, pl. 7, figs 7–8.
Echinocythereis karooma — Majoran 1995: app. ta.
Taracythere karooma (McKenzie, Reyment & Reyment 1993): — Ayress 1995: 918.
Echinocythereis karooma — Majoran 1996: 20, pl. 1, fig. 9, tas. 1,2, text fig. 6, apps 1,2.

Remarks. The Latrobe-1 specimens match closely in all details except for having a distinct subcentral tubercle contrasting with an indistinct one as noted in the original description. As the genus description for *Echinocythereis* corresponds more comprehensively with these specimens it has been retained in preference to *Taracythere* Ayress 1995.

Measurements. Average size: length 0.62 mm, height 0.36 mm, breadth 0.33 mm.

Material. Total 16 specimens: 1 C F, 8 LV, 6 RV, 1 fragment.

Figured Specimens. Fig. 4F (NMV P 312779); Fig. 4I (NMV P 312776). Both from sample 47B at 264.57 m.

Location and Age. Latrobe-1 bore, Dilwyn Formation including *Turritella* and *Trochocyathus* beds, 264.57 — 211.23 m; Early Eocene.

Sub-family TRACHYLEBERIDINAE Sylvester-Bradley, 1948
Trachyleberis Brady, 1898

Trachyleberis careyi
McKenzie, Reyment and Reyment, 1991
Figs 4J, N, P-Q

Trachyleberis careyi McKenzie, Reyment and Reyment 1991: 169–170, pl. 7, figs 11–12, pl. 10, figs 13–14.
Trachyleberis cf. *careyi* — McKenzie, Reyment and Reyment 1993: 105, Pl. 6, fig. 6.
Trachyleberis careyi — Neil 1997: 180, Figs 7A–F, H, J.

Remarks. Trachyleberis careyi from this location compares more closely with the patterns of ornament of the Paleocene figured specimens by Neil (1997) than with those from the Eocene (McKenzie, Reyment and Reyment 1991), but the anterior tooth is stepped as in the type specimens, not lobed as in Neil's specimens. The ornament ranged from blunt nodose tubercules to sharp bi-, tri- and polyfurcate

spines, some almost spatulate. The sizes were a little smaller than the McKenzie, Reyment and Reyment (1991) range of length 1.11–1.26 mm, height 0.66–0.72 mm and considerably less than Neil's largest specimens of 1.38 mm length.

That this large, robust, long-ranging species is found through most of this section is not surprising, having been identified in the older nearby Paleocene Pebble Point Formation (Neil 1997) and in southern Victorian Oligocene and Miocene (McKenzie et al. 1991). Its size and thickness of carapace would also reduce its chance of being corroded *in situ*. It was noticeably most abundant in the *Turritella* Bed.

Measurements. Length 0.95–1.1 mm, height 0.48–0.52 mm, breadth 0.5 mm.

Material. 30 specimens.

Figured Specimens. Fig. 4J (NMV P 312787) from sample 54 at 295.35 m; Fig. 4N (NMV P 312788) LV juv. from sample 46B at 260.6 m; Fig. 4P (NMV P 312789) from sample 40A at 211.23 m; Fig. 4Q (NMV P 312786) from sample 40A at 211.23 m).

Location and Age. Latrobe-1 bore, Dilwyn Formation, including Pember Mudstone, 329.64 m–211.23 m; Late Paleocene — Early Eocene.

Trachyleberis thomsoni?
Hornibrook 1952
Figs 4L-M

Trachyleberis thomsoni Hornibrook 1952: 33, pl. 3, figs 40, 41, 47.
Trachyleberis thomsoni — Ayress 1993: 133, text figs 3–5, pl. 9, Q, R.
Trachyleberis thomsoni — Majoran 1995: 78, 79, fig. 3G, Appendix. ta. p. 80.
Trachyleberis thomsoni — Majoran 1996: 20, 21, 24, 27, pl. 1 fig. 13, tas 1, 2, appendices 1, 2.
Trachyleberis thomsoni — Majoran 1996: fig. 9L, tas 1, 2.

Remarks. These Latrobe-1 specimens conform reasonably to Majoran (1995, 1996a, 1996b) and Ayress' (1993) illustrations but are much smaller than the New Zealand material. (Hornibrook 1952; Ayress 1993). The sizes of Majoran's specimens were calculated from his illustrations to be 0.94x0.48 (Majoran 1996), 1.0x0.5 (Majoran 1995) and 0.97x0.52 (Majoran 1996) — much closer to but still at the upper limit of the size-range found here. It was difficult to match this material or the SEM plates of Ayress and Majoran to the line drawings of Hornibrook's type species; the identification here is based on the work of the two later authors.

Measurements. Length 0.75–0.87 mm, height 0.4–0.5 mm, breadth 0.4 mm.

Material. 11 specimens including 2 carapaces plus fragments, all adult.

Figured Specimens. Fig. 4L LVF external (NMV P 312784) from sample 45B at 257.84 m; Fig. 4M RVM external (NMV P 312785) from sample 43B at 229.21 m.

Location and Age. Latrobe-1 bore, Dilwyn Formation including Rivernook Member and *Turritella* and *Trochocyathus* beds, ~297–229.21 m; ?latest Paleocene/?earliest Eocene — Early Eocene.

?**Trachyleberis** sp.
Fig. 4O

Remarks. Subrectangular with broad, low and indistinct ribs, sulci and tubercles. Anterior and posterior marginal denticulation present. Low ridges or series of suppressed nodes concentric to the anterior margin. Low subcentral tubercle. Internally, hinge amphidont with LV having anterior socket and postjacent tooth, bar smooth, posterior socket present. Central muscle scars indistinct. Left valve hinge has anterior socket, postjacent smooth tooth, smooth bar and long posterior socket. The tentative genus identification is based on the above features and the apparent cluster of barely visible tubercles anteroventral to the subcentral tubercle (more observable in the unscanned carapace from 43B). This species lacks the overall size or deep depression behind the spinose anterior margin of *T. careyi*. The specimens display the "blunter" posterior shape of *T. probesioides* Hornibrook, 1952 when viewed laterally and may be that species.

Measurements. LV, length 0.75 mm, height 0.35 mm.

C, length 0.8 mm, height 0.35 mm, breadth 0.31 mm.

Material. 1 C, 1 LV.

Figured Specimen. Fig. 4O (NMV P 312783) from sample 40A at 211.23 m.

Location and Age. Latrobe-1 bore, Dilwyn Formation, 229.21 — 211.23 m; Early Eocene.

Genus Indet.
Sp. nov.
Fig. 4K

Remarks. No clear taxonomic position has been found for this single reticulate fragment. The fine network of shallow fossae was roughly concentric about the prominent sub-central tubercle. Behind the anterior marginal denticles is a prominent flat-topped, sharp-edged, anterior marginal ridge. Ventrally there is part of a longitudinal ridge. There is a possibility of a reduced median ridge in the alignment of the longitudinal murae but no clear indication of a dorsal ridge. An eye tubercle might be present but the observed external protuberance may only be a hinge tubercle relating to the corresponding anterior hinge tooth socket. Internally the marginal zone is narrow with inner margin and line of concrescence coinciding and with no vestibules in available fragment; this could be indicative of a late stage instar, which would conform with the lack of observable hinge elements apart from the anterior socket. Adductor scars not visible.

Measurements. Height at hinge ear 0.33 mm.

Material. One right valve fragment, possibly late stage juvenile.

Figured Specimen. Fig. 4K (NMV P 312782) from sample 47B at 264.57 m.

Location and Age. Latrobe-1 bore, Dilwyn Formation, *Turritella* Bed, 264.57 m); Early Eocene.

REPOSITORY

All types and other specimens E. M. scanned in this paper are deposited in the Museum Victoria with the prefix NMV P.

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APPENDIX

Sampling Details. Depth information on most of the samples was available (Taylor pers. comm. 1970), those that were lacking have been estimated based on the available data, usual sampling intervals and positions of adjacent samples. The sample number is followed by the depth in metres, "~"indicates approximate position.

40A = 211.23; 41A = 217.32; 42A = 221.89; 42B = 224.64; 43B = 229.21; 44A = 242.32; 44B = 245.06; 45A = 254.2; 45B = 257.84; 46A = 259.38; 46B = 260.6; Sample 860-2 = 262.13-262.74; 47A = 262.74; 47B = 264.57; 48A = 288.4; 53B = 293.3; 54 = 295.35; 54A ~ 295.96; 54B ~ 296.5; 54C ~ 297; 54E = ~298; 54F ~ 298.7; 55 = 299.62; 55A = ~302; 56 top = 304.8; 56A ~ 305.41; 58A = 313.64; 61A = 329.64; 63A = 339.09; 64 = 344.42.

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STRATIGRAPHY AND PALAEOFLORA OF THE TRIASSIC COUNCIL TRENCH FORMATION, CENTRAL VICTORIA

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Webb J. A. & Mitchell M. M., Stratigraphy and palaeoflora of the Triassic Council Trench Formation, central Victoria. *Proceedings of the Royal Society of Victoria* 118 (1): 113–127. ISSN 0035-9211.

The Council Trench Formation is a thin unit that disconformably overlies Early Permian glacigenic sediments. It comprises pebble conglomerate, succeeded by cross-bedded lithic sandstone, then siltstone containing abundant plant fragments, and finally interbedded sandstone and pebble conglomerate. The Council Trench Formation was deposited by periodic high-energy flows within a shallow, south- to south-west-flowing river channel; the basal 4 m fining-upwards sequence probably represents sudden abandonment of the river channel due to a flood event. The sediments are dominated by locally derived granitic and metamorphic detritus.

The siltstone contains a poorly preserved but moderately diverse Triassic palaeoflora. This represents a swamp flora dominated by sphenophytes, including *Calamites*, together with liverworts (several species) and ferns (?5 species, including *Cladophlebis*). Elements that grew nearby on higher ground are also present: pteridosperms (?3 species of *Dicroidium*), cycadophytes (*Pseudoctenis*), ginkgoaleans (*Sphenobaiera* and *Ginkgo*), conifers (*Heidiphyllum*) and other gymnosperms (*Taeniopteris*, *Rochipteris* and ?*Fraxinopsis*). The presence of *Dicroidium* defines the Triassic age of the flora, which grew in a cool, high rainfall climate.

The Council Trench Formation probably represents the only Triassic sediments in Victoria, which at that time was largely an upland area with very little sediment deposition.

Keywords: Triassic, palaeoflora, Victoria, fluvial, Council Trench Formation.

TRIASSIC sedimentary rocks in Victoria have been recorded from only two localities, Bacchus Marsh (Bald Hill area) and Yandoit in the central highlands; in addition there are minor intrusions and acid volcanics of Triassic age in the eastern highlands. The Triassic cross-bedded quartz sandstone, siltstone and conglomerate exposed in the Council Trench at Bald Hill have been intermittently investigated since 1891, but only brief descriptions of the stratigraphy have been published. The purpose of this paper is to describe the Triassic Council Trench Formation in detail, revise the identifications of fossil plant fragments recovered from this sequence, and discuss their palaeogeographic and palaeoclimatic implications.

COUNCIL TRENCH FORMATION

Previous studies

The Council Trench was excavated in the 1870's on the southern flank of Bald Hill in a search for building stone, although none of the sandstone was ever used for this purpose (Robertson 1934). Ferguson (1891, 1920) described the geology of Bald Hill and submitted a collection of plant fossils from the Council Trench to McCoy, who assigned them a Triassic age based on identifications of *Schizoneura* and *Zeugophyllites* (McCoy 1892). McCoy (1894, 1898) later described additional species from the flora. However, there was some confusion about the relative stratigraphic positions of the Permian and Triassic strata at the site. This was clarified by Chapman (1927), who clearly assigned the 'upper beds at Bald Hill' (exposed in the Council Trench) to the Triassic, and distinguished them from the underlying Permian Bacchus Marsh Sandstone. Chapman described in detail the plant fossils found in the siltstone at the Council Trench; Douglas (1969, 1973) revised Chapman's identifications. Roberts (1984) mapped the area and provided a brief description of the sedimentology; he first used the name Council Trench Formation.

STRATIGRAPHY AND SEDIMENTOLOGY

Distribution and thickness

The Council Trench Formation crops out as dipping strata (25–30° towards 095°; Figs 1–3) over a very limited area on the southern flank of Bald Hill, adjacent to Tramway Lane, about 3 km northwest of Bacchus Marsh. Detailed mapping (Fig. 1) has shown that the outcrop area is less than 1 ha, considerably smaller than the 3 ha estimated by Roberts (1984) or the ~18 ha indicated on the Melbourne 1:250,000 Sheet. The formation extends for ~300 m along strike, and is truncated to the north and possibly also the south by a fault.

Jacobson & Scott (1937) considered that the mudstone/sandstone sequence at Bald Hill underlying the Council Trench Formation and overlying the Permian Mortons Conglomerate Member was also Triassic, but these beds contain Permian marine arenaceous foraminifera (O'Brien et al. 2003).

The maximum thickness of the Council Trench Formation is ~12 m, based on estimates of the location of the upper and lower boundaries, but only ~5 m is exposed (Fig. 2).

Type section

Roberts (1984) introduced the name Council Trench Formation but did not identify a type section. The best exposure is in the Council Trench itself, an excavation some 80 m long, and this is here designated the type section (Fig. 2). The eastern wall of the trench exposes the upper 3 m of the formation, and in the western wall the basal conglomerate crops out. The base of the trench is covered with rubble and soil, concealing an estimated 1.5 m of the lower part of the formation (Fig. 3).

Boundary relations

The Council Trench Formation disconformably overlies marine ferruginous siltstones and sandstones of the Early Permian Bacchus Marsh Formation (Roberts 1984, O'Brien et al. 2003). The stratigraphic relationship between the Permian and Triassic sediments has been variously suggested as conformable (Mahoney 1937) and faulted (Bowen 1959), but the current mapping (Fig. 1) and the ages of the two units makes it clear that the boundary is a disconformity.

Overlying the Council Trench Formation are weathered basalts of the Paleocene Pentland Hills Volcanics and ferruginous coarse sandstones of the Oligocene-Miocene Werribee Formation (Roberts 1984; Holdgate & Gallagher 2003). The boundary is probably a disconformity to slight angular unconformity; bedding in the overlying Werribee Formation at Bald Hill is difficult to find due to poor outcrop, but the general dip is moderately steep towards the east, reflecting Cainozoic movement of the nearby Rowsley Fault.

Stratigraphic sequence

The Council Trench Formation consists of interbedded sandstones, conglomerates and siltstones (Figs 2, 3). The basal unit is a very poorly sorted coarse pebble conglomerate about 50 cm thick, that varies laterally from massive, moderately well sorted and clast-supported to plane-laminated, poorly sorted and matrix-supported, with granules and pebbles up to 5 cm across surrounded by a matrix of coarse sandstone (Fig. 3D). The conglomerate is covered in places with a ferruginous reddish yellow weathering rind. The pebbles are subrounded to well-rounded and frequently ovoid in shape; they consist predominantly of milky vein quartz, with sporadic clasts of black chert and pale green slate up to 15 cm long. The vein quartz is commonly deformed, as shown by its strongly undulose extinction in thin section. The coarse sandstone matrix consists of abundant quartz clasts (mostly granitic, with some vein quartz), sparse perthitic K-feldspar (5–10%) and rare tourmaline grains in a ferruginous cement, with small patches of silty clay. Many of the sand grains and pebbles are fractured; the cracks are infilled with ferruginous cement.

Overlying the conglomerate is at least 2 m of medium-grained pale grey to yellow-brown lithic sandstone (Fig. 3A), commonly displaying well-developed liesegang banding, with rare 1 cm thick siltstone beds; one of these has been broken into mudchips, forming a thin interbed of mud clast conglomerate. The sandstone is either plane-laminated or trough cross-bedded; the upper part of this unit comprises a single trough-cross-bed set approximately 1 m thick, giving a palaeocurrent direction towards the southwest. The mud clast conglomerate interbed is about 5 cm thick, and contains abundant siltstone rip-up clasts up to 10 cm long and 1 cm thick, along with well rounded quartz granules to

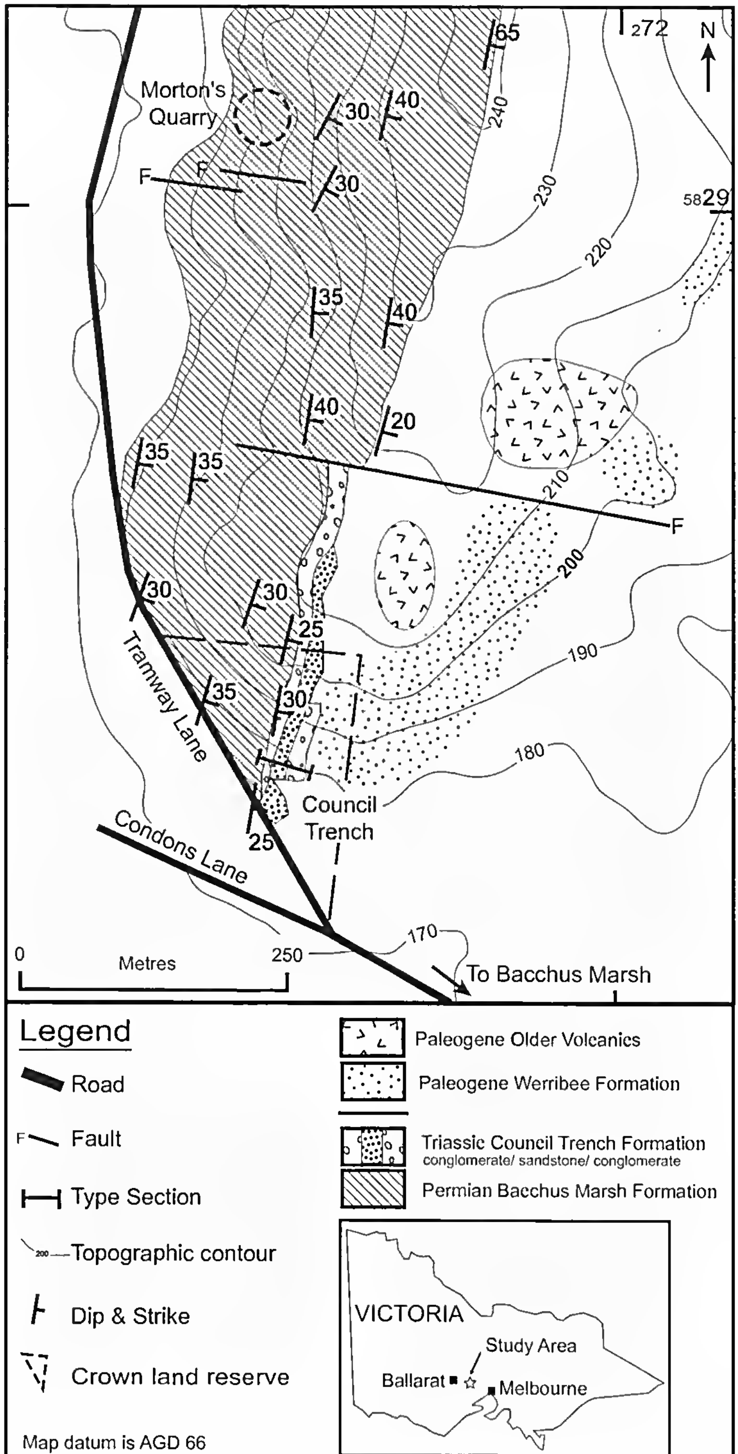

Fig. 1. Geological map of the southern flank of Bald Hill, near Bacchus Marsh, showing the outcrop of the Council Trench Formation and underlying and overlying units. Contour interval 10 m.

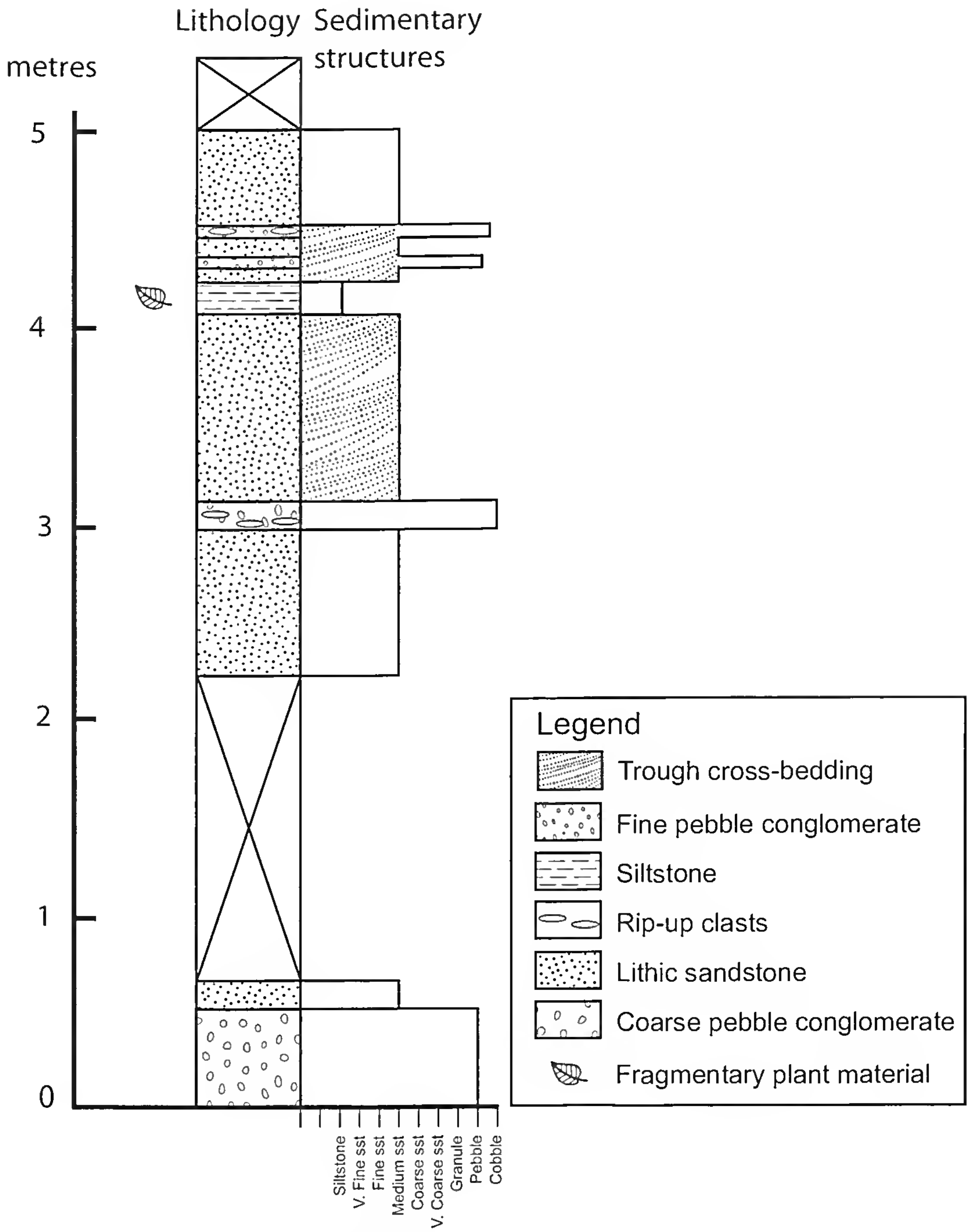

Fig. 2. Type section of the Council Trench Formation at the Council Trench, Bacchus Marsh; composite of exposures in western and eastern walls of trench.

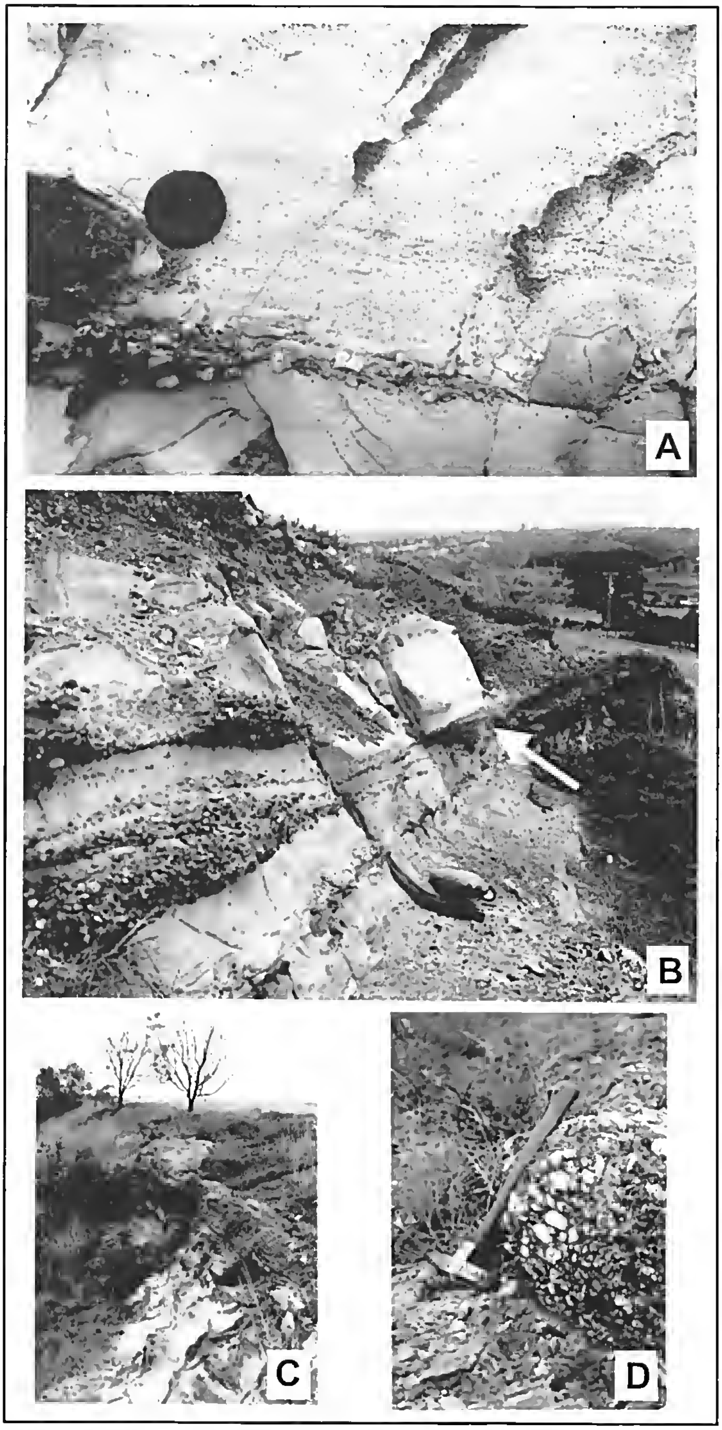

Fig. 3. Outcrop of Council Trench Formation within the Council Trench. (A) Central sandstone unit with liesegang banding and pebble layer with mud chips; lens cap in left of photo is 55 mm in diameter. (B) Upper lensoidal conglomerate and sandstone; fossiliferous siltstone arrowed. (C) General view showing the dip of the units to the east. (D) Pebbles of milky vein quartz in basal conglomerate; geological hammer is 33 cm long.

pebbles (up to 7 cm across) and tabular clasts of low grade metamorphics up to 15 cm long.

Above the sandstone is a 20 cm bed of pale grey massive siltstone, which contains abundant scattered fragmentary plant impressions. All the recently collected plant fossils from the Council Trench Formation came from this bed. The fossil material described by McCoy (1892, 1894, 1898), Chapman (1927) and Douglas (1969, 1973) was collected from a laterally correlative thicker siltstone unit; it is possible to accurately correlate the stratigraphic section given by Chapman (1927) with that currently exposed.

Overlying the siltstone is about 1 m of interbedded medium-coarse grained sandstone and lenses of very poorly sorted clast-supported fine pebble conglomerate with a fine-medium sandstone matrix (Fig. 3B), displaying low-angle cross bedding and a southerly palaeocurrent direction. The conglomerate bands contain clasts up to 1 cm diameter of chert, slate (both containing thin quartz veins), subrounded milky vein quartz (commonly with intergrown muscovite) and granitic quartz (locally intergrown with feldspar). In addition, there are polycrystalline quartz clasts that appear to represent granitic quartz veins; they are clear, unlike the very cloudy vein quartz grains. Both types of vein quartz clasts commonly have strongly undulose extinction, indicating deformation of the veins after they had crystallised. One conglomerate band also contains rip-up clasts of siltstone up to 16 cm long. The sandstone matrix comprises clasts of granitic quartz, perthitic K-feldspar, microcline, slate, muscovite flakes and rare hornfels in a ferruginous cement with patches of silt. The very high volume of exsolution lamellae in the feldspar grains indicates a high temperature granitic origin. As in the lower conglomerate, many of the sand grains and pebbles in the upper conglomerate and sandstone contain cracks infilled with ferruginous cement.

Environment of deposition

The succession is fluviatile and was deposited by a south- to southwest-flowing river; the thickness of the cross-bed set (~1 m) gives the minimum depth of the channel. The maximum size of the quartz clasts in the conglomerate (5 cm) and the presence of rip-up clasts indicate periodic high-energy deposition within the channel; the strong fragmentation of the plant fossils in the siltstone also suggests high-energy flows. The fining-upwards sequence (conglomerate to siltstone) that makes up the basal 4 m of the exposure represents progressive or sudden abandonment of the shallow river channel (channel migration or a flood event respectively). The comminuted nature of the plant debris within the siltstone could be due to flood destruction of a riverbank swamp. The overall thinness of the Triassic strata and lack of exposure preclude more detailed interpretation.

Provenance

The Triassic sediments represent erosion of a low-grade metamorphic and granitic terrain, as shown by the milky vein quartz/chert/slate and granitic quartz/perthitic K-feldspar/microcline/hornfels clasts respectively. The derivation of the sediments was probably local. A large area of Ordovician slates extends to the north and presently crops out within 3 km of the Council Trench; the Devonian Ingliston Granite is exposed only 7 km to the west, and the Baynton and Pyalong granites lie 50 km to the north. However, the Triassic sediments could just as easily have been derived by erosion of nearby exposures of Permian tillites, which contain abundant subrounded to well-rounded gravel-sized clasts of granite, vein quartz and chert, together with large amounts of finer-grained low grade metamorphic detritus. This material was picked up by the north-flowing Permian glaciers from river gravels and exposures of Ordovician slates and Devonian granites (e.g. You Yangs Granite) to the south (O'Brien et al. 2003). The Council Trench conglomerates contain a higher proportion of quartz gravel than the Permian tillites, perhaps due to destruction of the less durable granite and metamorphic clasts during erosion and river transport.

Duddy (2003) used the presence of apatite and zircon grains with Triassic fission track ages to infer that the Council Trench sandstone is a volcanogenic sediment. However, although it may contain a small component of volcanic ash, probably derived from the Late Triassic eruptions to the south in Tasmania (Forsyth 1989), the sandstone is clearly dominated by granitic and metamorphic detritus.

PALAEOBOTANY

The siltstone towards the top of the Council Trench Formation contains very abundant comminuted plant debris preserved as iron-stained impressions (none of the original plant material is present); most

fragments are <1 cm across and unidentifiable. Apart from common sphenophyte stem pieces, the Council Trench Formation flora contains sparse pinnules (sometimes with venation visible) and rare larger leaves (almost never complete). As a result, only a few plant specimens can be identified to species level, although many can be confidently assigned to genera. Identifications are discussed briefly below, based on new specimens collected during the present study and re-assessment of previously described material; many of the previous species names were in need of revision. Formal taxonomic descriptions are not warranted for the Council Trench Formation flora due to the fragmentary nature of the material. All specimens are held by the Museum of Victoria.

Bryophyta

Several specimens of thalloid liverworts are present (Figs 4A-E), including three identified by Chapman (1927) as *Baiera darleyensis* (figs 32, 33, 34); these lack the multiple subparallel veins characteristic of ginkgophytes. Two more specimens were identified during the present study. More than one species may be present, as the specimens vary in degree of bifurcation (single to triple) and width (1–2.5 mm), and may have faint midribs.

Sphenophyta

Sphenophyte stems are the most common element of the Council Trench Formation flora, and many were collected during the present study (Figs 7B, C). Chapman (1927, Figs 1–17, 35) illustrated numerous stems that he referred to *Schizoneura* and *Phyllotheca*; because the leaves and nodal diaphragms are rarely present and not well preserved, it is difficult to assign these stems confidently to a genus. However, in some specimens the internodal ribs alternate across the node, indicating that attribution of these stems to *Calamites* is most appropriate. More than one species of sphenophyte is present, as the internode ribs vary from numerous, subdued and closely spaced (Fig. 7B) to few, widely spaced and prominent (Fig. 7C). Sphenophyte (equisetalean) stems often dominate the vegetation of Triassic lake margin and swamp facies worldwide (Holmes 2000).

The specimen named by McCoy (1894) as the new species *Ptilophyllum officeri* was identified as *P. pecten* by Chapman (1927, fig. 36), but Douglas (1969, Fig. 2,1) resurrected the original name. A close examination of this specimen during the present study showed that it is a poorly preserved stem of *Calamites*. The 'pinnae' are internode ribs and the 'rachis' is a node; Chapman's and Douglas' illustrations orient the specimen on its side with respect to its growth position. Chapman's depiction of the pinnae is very inaccurate and no veins are present.

Fern-like foliage

A fragment of a bipinnate frond with small elongate (4–5 × 1.5 mm) subopposite pinnules and indistinct venation (Figs 4J, 7D) is referable to *Cladophlebis*; in gross morphology the specimen resembles *C. tenuipinnula* Holmes 2003, but details of the venation and overall frond morphology are needed for a positive identification. *Cladophlebis* was erected for sterile foliage of probable fern affinities.

The specimen illustrated by Chapman (1927) as fig. 19 most likely represents a second species of *Cladophlebis*; it has ovate pinnules (8 x 4 mm) with enrolled margins and an acute inclination to the rachis; there is a strong midvein and the secondary veins may bifurcate once, and run more or less straight to the margin (Fig. 4K). There is another specimen that may belong to this species in the new collection (Fig. 4O); it has slightly lobed margins and the veins rarely fork twice.

One specimen is a small oblong 5 x 2 mm pinnule with a contracted base, bifurcating venation and no midvein (Fig. 4F); it resembles some species of the fern-like foliage *Nymboidiantum* Holmes 2003.

There are numerous isolated pinnules in the Council Trench Formation flora that may represent fern foliage, e.g. the specimen illustrated by Chapman (1927) as fig. 21. They generally have a tapering lanceolate shape, a strong midvein and secondary veins that bifurcate twice and travel more or less straight at a very acute angle, and resemble some species of *Cladophlebis*, e.g. *C. australis* (Herbst 1978). The specimens named *Coniopteris delicatula* by Chapman (1927, figs 24, 28) may also be ferns, but are too fragmentary for identification; the feathery appearance of the pinnules is due to their poor preservation rather than their original morphology.

Another probable fern (Fig. 4G) is a fragment of a bipinnate frond with distinctively shaped pinnae that have crenate margins; the veins fork twice or

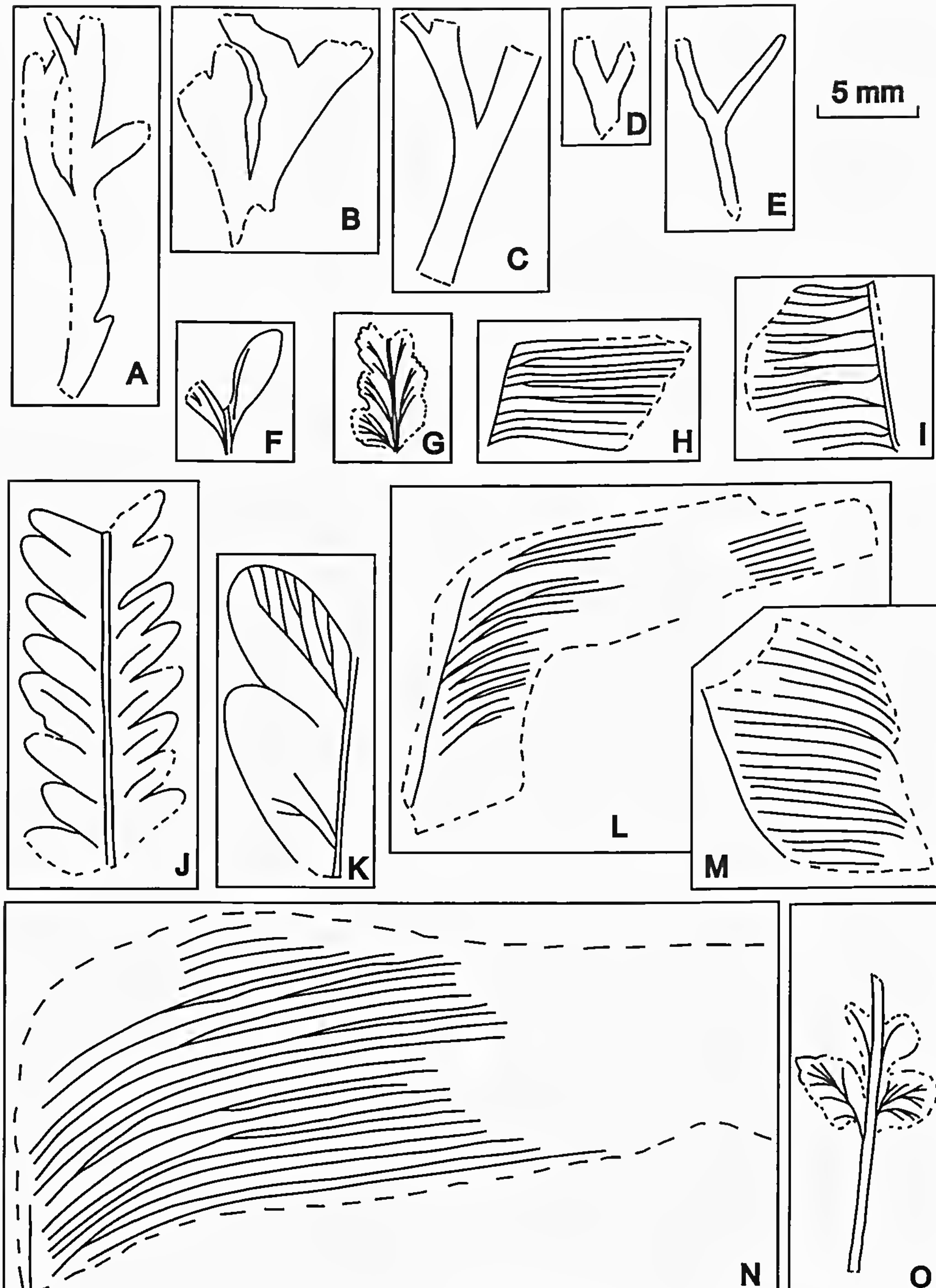

Fig. 4. Liverwort, fern, cycadophyte and gymnosperm incertae sedis fossils from the siltstone unit in the Council Trench Formation (see Fig. 2 for stratigraphic location). All figures to same scale. A-E thalloid liverworts; A - P16067 (Fig. 34, Chapman 1927), B - P160539, C - P16064 (Fig. 33, Chapman 1927), D - P221282, E - P16062 (Fig. 32, Chapman 1927). F ?*Nymboidiantum* sp., P160527. G Fern gen. et sp. indet., P221296. H, I *Pseudoctenis* sp. (H - P221283, I - P1481). J *Cladophlebis* sp. A, P221297. K *Cladophlebis* sp. B, P16065 (Fig. 19, Chapman 1927). L, N *Taeniopteris* cf. *wianamattae*; L - P221284, N - P4015 (Fig. 51, Chapman 1927). M *Taeniopteris* sp., P160522. O *Cladophlebis* sp. B?, P221295.

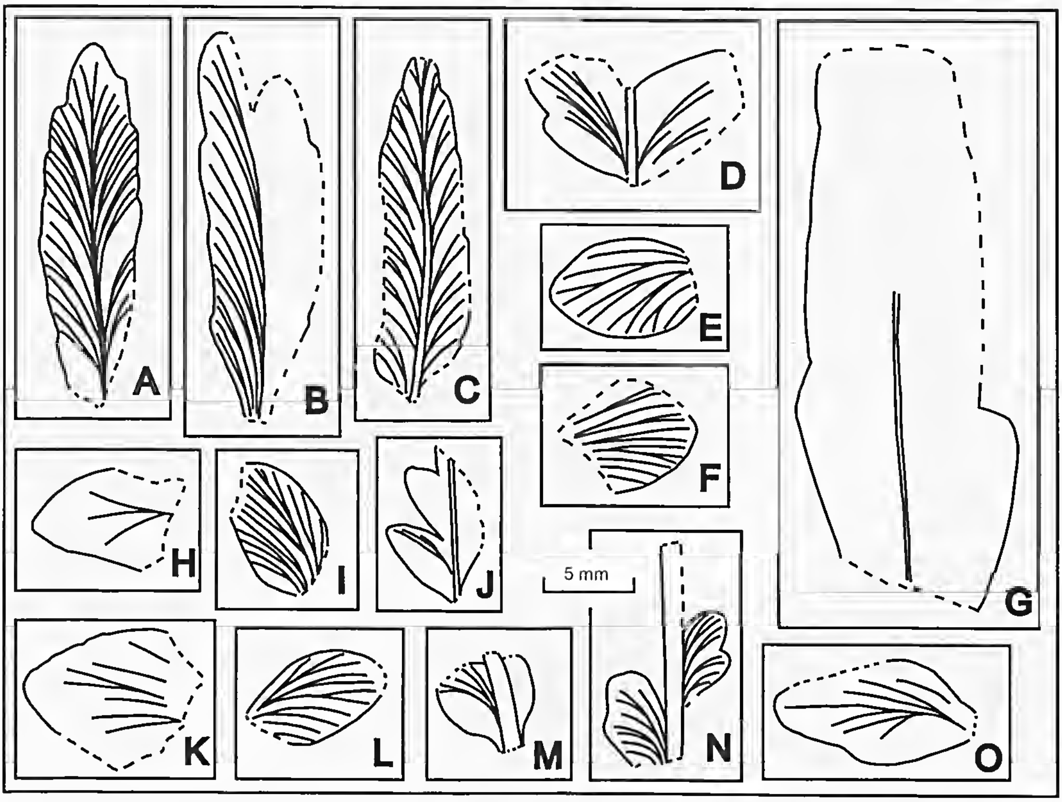

Fig. 5. *Dicroidium* fossils from the siltstone unit in the Council Trench Formation (see Fig. 2 for stratigraphic location). All figures to same scale. A-D, G *Dicroidium dubium* complex; A – P16058 (Fig. 20, Chapman 1927), B – P221286, C – P221291, D – P221285, G – P221287. E, F, H-L *Dicroidium odontopteroides* complex, ovate morphology; E – P160541, F – P221289, H – P221299, I – P221290, J – P221300, K – P2660, L – P221292. M, N *Dicroidium* cf. *odontopteroides* complex; M – P221294, N – P221293. O *Dicroidium odontopteroides* complex, lanceolate morphology, P221288.

three times and terminate in the acute apices of the crenations. The specimen is not large enough to be identifiable.

Pteridospermophyta

Chapman (1927) identified three species (four specimens) of *Thinnfeldia* in the Council Trench Formation flora; southern hemisphere species of this genus are now referred to *Dicroidium*, and are considered to be diagnostic of Triassic floras (Holmes & Anderson 2005). Townrow (1957) and Douglas (1969) regarded the assignation of the Council Trench specimens to *Dicroidium* as doubtful, and close examination of them during the present study showed that one (Chapman 1927: fig. 30) is unidentifiable as it lacks details of venation, and two (Chapman 1927: figs 19, 21) are probably pinnules of fern-like foliage (as discussed previously). However, the fourth specimen (Chapman 1927: fig. 20) shows the characteristic *Dicroidium* venation of arching secondary veins that commonly bifurcate twice (Fig. 5A). This pinnule has a poorly defined midvein, definitive of alethopteroid *Dicroidium* venation, and an indistinct but apparently faintly lobed margin. Several additional pinnules with alethopteroid venation and slightly to clearly lobed margins have been collected (Figs 5B-D, G, 7G), and they probably represent the bipinnatifid *D. dubium* complex of Holmes & Anderson (2005). They vary in width from 5–10 mm and in length from 1–>3 cm, and are smaller than most of the examples of this species figured by Holmes & Anderson (2005) and Anderson & Anderson (1983). Although they resemble some species of *Pachypteris*, the venation is characteristic of *Dicroidium*.

Several other isolated pinnules with a blunt ovate shape (6–9 × 4–7 mm), no midrib and arching veins

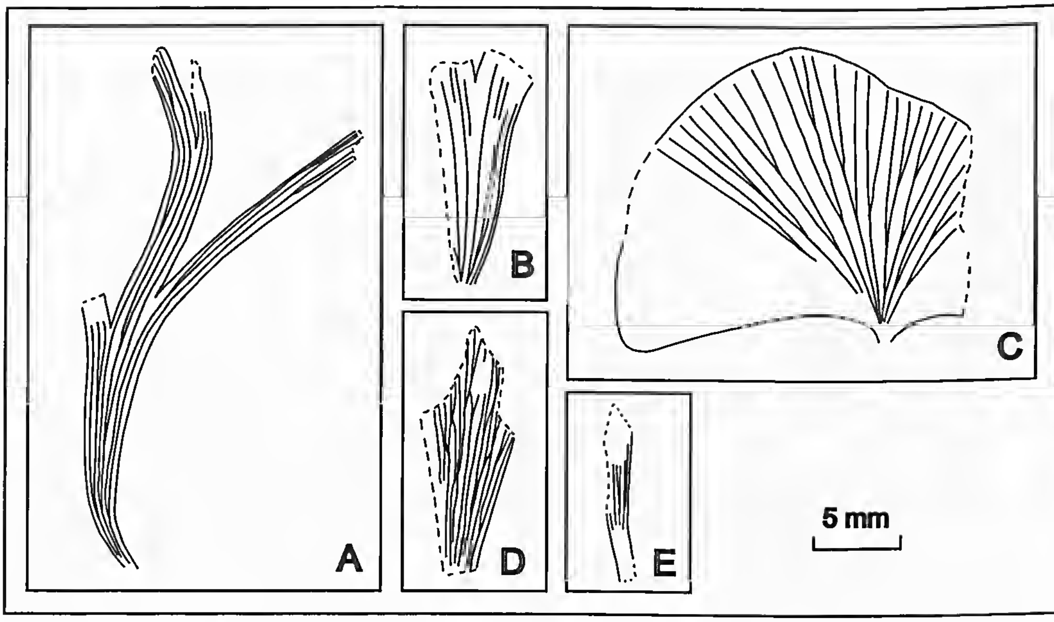

Fig. 6. Ginkgophyte and gymnosperm incertae sedis fossils from the siltstone unit in the Council Trench Formation (see Fig. 2 for stratigraphic location). All figures to same scale. A, B *Sphenobaiera* sp. cf. *S. schenckii*; A – P846, B – P16080 (Fig. 29, Chapman 1927). C *Ginkgo antarctica*, P221281. D *Rochipteris* sp., P 160529. E *?Fraxinopsis* sp., P221298.

that commonly bifurcate twice or more (Figs 5E, F, H-L, 7I) can be identified as the semi-orbicular to broadly triangular morphology of the *D. odontopteroides* complex (Holmes & Anderson 2005). This morphology is particularly characteristic of *Dicroidium* and definitely indicates the presence of this genus in the flora.

Some slightly more elongate pinnules (10–11 × 6 mm; Figs 5O, 7E) are probably referable to the lanceolate morphology of the *D. odontopteroides* complex as defined by Holmes & Anderson (2005).

Some tiny ovate pinnules (3–5 × 2.5–3 mm; Figs 5M, N), a few with lobed margins, have odontopteroid venation and could represent a very small variant of the *D. odontopteroides* complex or a separate species; the smallest pinnules of this complex illustrated by Anderson & Anderson (1983) are about the same size.

Cycadophyta

There are two fragments of cycadophyte pinnae in the collection (Figs 4H, I, 7F). Both show only the pinna base, which is slightly contracted; the pinnae are 6–8 mm wide with 10–12 veins/5mm (vein density measured perpendicular to the venation); the veins may fork once near the rachis. These specimens probably belong to *Pseudoctenis*, but because the apex of the pinna is not preserved no specific identification can be made.

Ginkgoales

Among the better preserved of the Council Trench plants are the ginkgoalean leaves. The specimen referred to *Ginkgoites digitata* by Chapman (1927, fig. 29) should be referred to *Sphenobaiera*, based on its lack of a petiole and acute base (Fig. 6B). An almost complete specimen of the same species (Figs 6A, 7A) shows that the leaf is about 35 mm long and a maximum of 4–6 mm wide with a very narrow, acute, non-petiolate base. It is divided into three segments by moderately deep incisions that extend to 10–15 mm from the base of the leaf, and one segment is again divided by a shallower incision. Veins radiate from the base and dichotomose up to three times; vein density is ~16/5mm. This species is similar to the South African and Australian Triassic species *S. schenckii* in shape and venation but is smaller than the average leaf of this species; it is about the

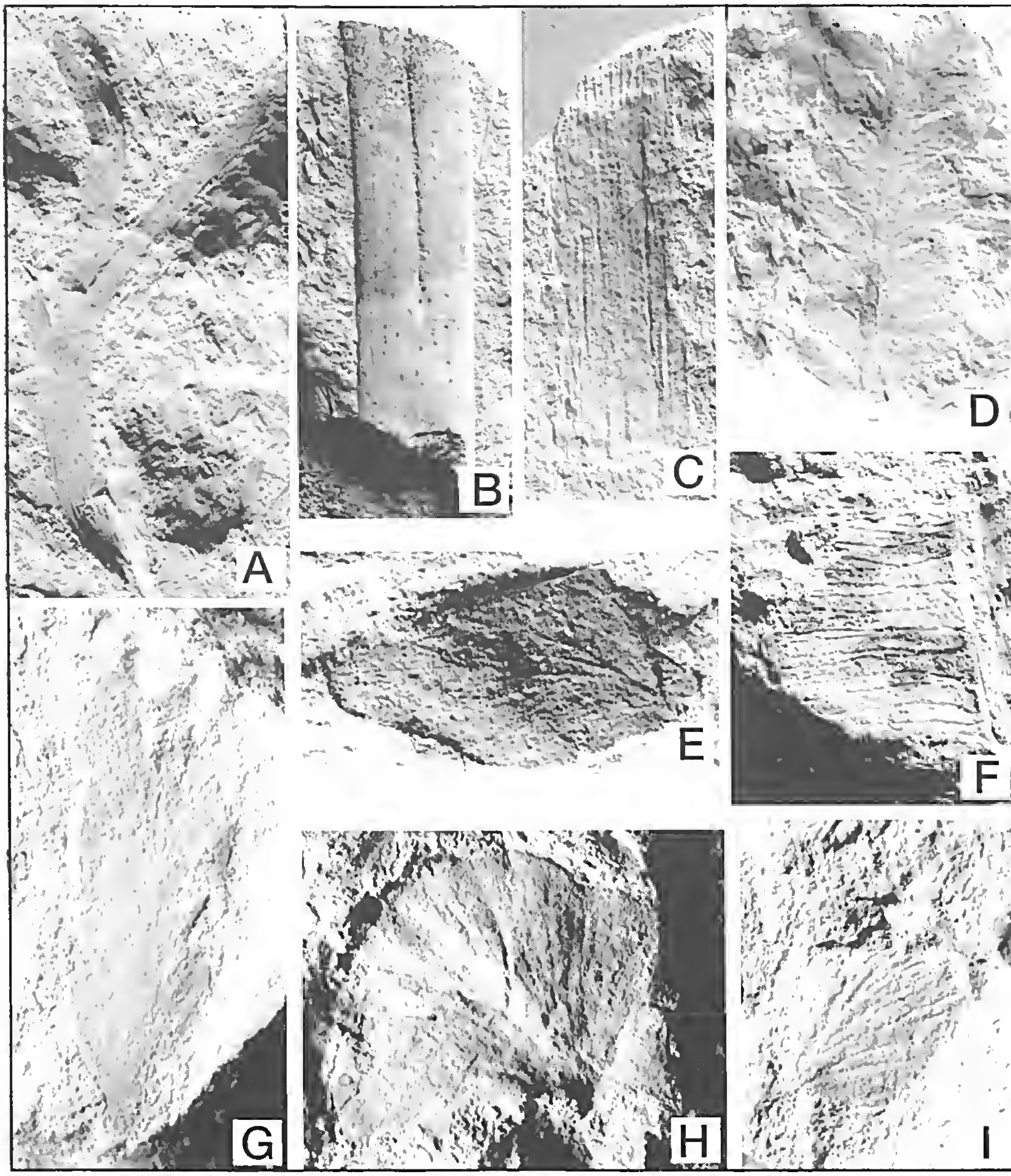

Fig. 7. Plant fossils from the siltstone unit in the Council Trench Formation. A *Sphenobaiera* sp. cf. *S. schenckii*, P846, x2.6. B, C Sphenophyte stems (B - P1150, x1.3; C - P1302, x 1.3). D - *Cladophlebis* sp. A, P221297, x 2.8. E - *Dicroidium odontopteroides* complex, lanceolate morphology, P221288, x 4.5. F - *Pseudoctenis* sp., P1481, x 3.7. G - *Dicroidium dubium* complex, P221286, x 3.0. H - *Ginkgo antarctica*, P221281, x 2.3. I *Dicroidium odontopteroides* complex, ovate morphology, P221292, x 3.6.

same size as the smallest specimens illustrated by Anderson & Anderson (1989).

Another ginkgoalean leaf (Figs 6C, 7H) can be identified as *Ginkgo*, based on its very obtuse petiolate base. The leaf is small (17 x 25 mm) with an entire margin and radiating veins that commonly bifurcate twice. It is best assigned to *G. antarctica*, which is known from the Triassic of South Africa

and eastern Australia (Hill et al. 1965; Anderson & Anderson 1989); it has a slightly higher basal angle than the maximum known for this species (200° rather than 160°), and is smaller, although it does match the smallest specimens of this species figured by Anderson & Anderson (1989).

Coniferales

The specimen of *Phoenicopsis elongatus* (Chapman 1927; fig. 27) is a narrow strap-shaped leaf 3 mm wide and over 30 mm long, with indistinct parallel venation. It can probably be referred to the voltzialean conifer species *Heidiphyllum minutifolium* known from the Triassic of southeast Queensland (Walkom 1924; Anderson & Anderson 1989).

Petriellales

Chapman (1927; figs 39, 44, 45) figured as *Psygmophyllum fergusoni* Chapman 1927 a flabellate leaf with anastomosing venation (Fig. 6D); leaves with this morphology are now referred to *Rochipteris* (Herbst et al. 2001; Barone-Nugent et al. 2003). The specimens are too fragmentary for specific assignation.

Gymnospermae incertae sedis

A fragment of a large strap-shaped leaf was described as the new species *Taeniopteris sweeti* by McCoy (1898) and assigned to *T. wianamattae* by Chapman (1927, fig. 51; Fig. 4N herein), and there is another fragment in the collection (Fig. 4L). This species is up to 95 mm wide and has distinctive venation, with the veins curving strongly as they leave the midrib and then running straight and parallel to the margin at 75–80° to the midvein. Some veins fork once, usually near the midvein, and rarely a second time, and have a density of 9–13 veins/5mm. From its size and venation it could be retained as *T. wianamattae*, which is known from the Triassic of the Sydney Basin (Walkom 1925), but the apex and base of the leaf are needed for complete identification. It should be noted that Anderson & Anderson (1989) synonymised *T. wianamattae* with the South African species *T. homerifolius*, but the latter species lacks the strong curvature of the veins as they leave the midvein and is separate.

A narrower strap-shaped leaf, only 15–20 mm wide, is also present (Fig. 4M), with similar venation to *T. sp.* cf. *T. wianamattae*, but slightly more widely spaced (8 veins/5mm). This is probably a separate species of *Taeniopteris*, but is too fragmentary for identification.

One specimen in the new collection may belong to *Fraxinopsis* (Fig. 6E); this is a distinctive gymnosperm fruiting body consisting of an ovoid seed body attached to a lanceolate, parallel-veined wing, and is known only from Late Triassic strata (Retallack 1977; Webb 1982; Anderson & Anderson 1989). The Council Trench specimen lacks the seed body but the wing is moderately well preserved; it is small (16 x 2 mm) with probably 7–8 veins that diverge from the base and run straight and parallel, forking sparsely; no anastomoses are visible. This specimen is of similar size to *F. minor* from the Late Triassic of Argentina (20–25 mm long; Axsmith et al. 1997) and the smallest specimens of *Fraxinopsis* illustrated by Anderson & Anderson (1989) from the Late Triassic of South Africa.

Overall composition of flora

Redescription of the Council Trench Formation flora has shown that it is moderately diverse, with at least 20 species; identifiable specimens are dominated by sphenophytes, and there are also several species of probable ferns and liverworts, together with pteridosperms (*Dicroidium*), ginkgophytes and cycadophytes, as well as conifers and other gymnosperms. The abundant sphenophyte stems are typical of swamp vegetation; the liverworts and ferns might also have grown in the swamp. The other plants probably grew as shrubs or small trees on more elevated ground nearby (e.g. Retallack 1977, Anderson & Anderson 1989); their remains were presumably swept into the river during a flood event.

Age

The pinnules of *Dicroidium odontopteroides* and *D. dubium* in the Council Trench Formation give a Triassic age for the palaeoflora (Retallack 1977, Webb 1982, Anderson & Anderson 1983, 1989). If *Fraxinopsis* is indeed present, it restricts the age to Late Triassic. Chapman (1927, p. 148) placed the formation "in the Trias, with a strong leaning towards the Jurassic..." The sediments are too weathered to yield palynomorphs (Douglas 1969).

Duddy (2003) placed an older limit of about 235 Ma (mid-Triassic) on the age of the Council Trench

Formation, based on the presence of apatite and zircon grains with fission track ages of 200–250 Ma (±95% confidence). These grains probably represent a small component of volcanic ash from contemporaneous basaltic eruptions in Tasmania (Forsyth 1989) and/or acidic eruptions in eastern Victoria.

VICTORIA IN THE TRIASSIC

Other Triassic outcrops in Victoria

Triassic sediments have also been recorded from Old Nuggety Gully, near Yandoit Hill in central Victoria, where small pieces of grey mudstone, collected from an old adit, contain fragmentary plant impressions identified by Chapman (in Mahoney 1937) as probably Triassic in age. Similar poorly preserved material was also collected at Parkers Gully, 3 km SW of Old Nuggety Gully.

Douglas (1969) isolated well-preserved cuticle of the Triassic genera *Xylopteris* (*Dicroidium*) and *Rienitsia* from the Museum of Victoria collection from Old Nuggety Gully, together with a Triassic microflora dominated by *Alisporites*. However, recollection of the locality has yielded only Permian microfloras (J.G. Douglas, pers. comm.), and the plant fossils occur in an apparent tillite (Bowen 1959; Douglas 1988). Given the inability to confirm the origin of the original sample material, this occurrence must be regarded as uncertain; it is possible that the Museum of Victoria material examined by Douglas (1969) was in fact from a Triassic locality interstate (J.G. Douglas, pers. comm.).

In eastern Victoria, near Benambra, the intrusions, trachyte lavas and pyroclastics of the Mt Leinster Igneous Complex are probably Middle-Late Triassic in age (McDougall & Wellman 1976).

Palaeogeography

Throughout the Triassic, Victoria was largely an upland area and subject to erosion. This is based on the very minor sediment accumulation in Victoria at the time; there were no equivalents of the subsiding basins to the south in Tasmania and the Sydney Basin to the north in New South Wales. Palaeocurrents in the Tasmanian Triassic succession are predominantly towards the east and southeast (Forsyth 1989), and in the Early-Middle Triassic of New South Wales towards the north and northeast (Standard 1969), indicating that Victoria occupied a topographically high area at that time. The southeastern highlands, of which Victoria formed a part, were uplifted during the Early Triassic Hunter-Bowen Orogeny (O'Sullivan et al. 1996), and the resulting erosion supplied the influx of sand and gravel into the basins of southeastern Australia in the Triassic (Struckmeyer & Totterdell 1990).

Palynological studies from the Early Cretaceous sediments of Victoria occasionally report abundant Triassic spores and pollen, derived from erosion of Triassic sediments. Although this has been used as evidence that Triassic strata in Victoria were originally thicker and more extensive (Duddy 2003), the Triassic palynomorphs were more likely derived from erosion of the extensive Triassic sedimentary sequence in Tasmania.

Palaeoclimate

The diverse palaeoflora and the sedimentological evidence for periodic high-energy flows in the river channel suggest a relatively humid palaeoclimate during the Triassic in Victoria. Throughout eastern Australia, the Triassic was characterised by relatively high rainfall (Balme et al. 1995).

Compared to Triassic floras in New South Wales, Queensland and South Africa (Webb 1982; Webb & Holmes 1982; Anderson & Anderson 1989; Holmes 2000, 2003; Holmes & Anderson 2005), the Council Trench Formation flora is characterised by a higher proportion of bryophytes and generally small foliage, even given the fragmentary nature of the plant fossils, e.g. the pinnules of *Dicroidium dubium* and the leaves of *Ginkgo antarctica* and *Sphenobaiera schenckii* are smaller than in the other Gondwana floras of this age. The Council Trench Formation flora shares these characteristics with the Late Triassic floras of Tasmania (Balme et al. 1995). Today leaf size tends to be smaller and bryophytes more abundant at lower temperatures, so the Tasmanian and Victorian floras probably grew in a cool climate (Townrow 1964; Balme et al. 1995); the palaeolatitude of Victoria and Tasmania in the Triassic was approximately 70°S (Veevers 2000).

CONCLUSIONS

The Council Trench Formation is a thin sequence of cross-bedded sandstone, pebble conglomerate and fossiliferous siltstone deposited by periodic high-energy flows within a shallow, south- to southwest-

flowing river channel; there is some evidence for sudden abandonment of the river channel due to a flood event. The sediments are dominated by granitic and metamorphic detritus and were derived locally. The siltstone contains a poorly preserved but moderately diverse Triassic palaeoflora of at least 20 species. This represents a swamp flora dominated by sphenophytes, together with liverworts and ferns, and also contains elements that grew nearby on higher ground (pteridosperms, cycadophytes, ginkgoaleans, and conifers). The flora grew in a cool, high rainfall climate.

The Council Trench Formation probably represents the only Triassic sediments in Victoria, and shows that at this time Victoria was largely an upland area with very little sediment deposition, in contrast to the subsiding basins to the northeast and southeast.

ACKNOWLEDGEMENTS

This paper is dedicated to Prof. Neil Archbold, Deakin University, who recently passed away. He provided the initial impetus to the study and assisted with mapping of the Council Trench Formation. The Museum of Victoria is thanked for the loan of specimens. All specimens described and figured in this study are in the Museum of Victoria collections.

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PLANT ECOLOGICAL STUDIES IN THE BRISBANE RANGES

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The Brisbane Ranges exhibit a range of vegetation types that vary according to topography, geology and soil type. On the plateau, average grain size of the lateritized sandy clays of the Tertiary capping decreases from east to west, which affects both soil nutrient status and moisture relationships. Sandy loams in the east support sclerophyll open-forest of *Eucalyptus obliqua-E. macrorhyncha* with shrub browsers (Black-tailed wallabies) whereas fine sandy loams in the west support grassy woodlands of *E. ovata, E. viminalis* and *E. pauciflora* with grazers (Eastern Grey kangaroos). In wet years, waterlogging due to perched water tables in the more nutrient-rich grassy woodland soils is a factor that reinforces the division between grassy and sclerophyll shrub understoreys on the plateau. Although changes in the sclerophyll open-forest have occurred due to fires in the past, profound changes have occurred since the introduction of *Phytophthora cinnamomi* at least four decades ago. Changes in the grassy woodlands include expansion of areas of *Allocasuarina littoralis* scrub and the invasion by *E. obliqua* into *E.ovata-E. viminalis-E.pauciflora* woodlands since the 1950s and 1970s. The dissected area of Ordovician rocks towards the Rowsley Fault scarp is a complex continuum of vegetation types, involving mixtures of *E. macrorhyncha* with up to seven other eucalypts, the communities of which vary floristically and structurally with slope and aspect. Sandy lunettes on the lee sides of plateau swamps, now commonly vegetated by *E. viminalis* and *Pteridium esculentum*, suggest times of greater aridity during late Quaternary times. The existence of many species in the Brisbane Ranges with affinities to semi-arid areas north of the Great Dividing Range suggests that much more arid conditions existed in the past. The Brisbane Ranges therefore occupy an important plant geographic link between eastern and western Victoria.

Keywords: Sclerophyll forest, Grassy woodland, Edaphic control, Waterlogging, Fire, *Phytophthora cinnamomi*, Vegetation dynamics

THE BRISBANE Ranges are characterized by the Rowsley fault scarp, which terminates the eastern edge of the Western Highlands Plateau between Bacchus Marsh and Geelong. The Ranges are of interest ecologically since the plateau and adjacent dissected slopes occur in a rain-shadow (Figure 1), and contain a variety of sclerophyllous, shrubby eucalypt communities and grassy eucalypt communities. Most of the grassy woodlands to the west were cleared during the pastoral expansion in the mid-1800s and some disturbance has occurred in forested areas due to firewood harvesting, light grazing and recurrent bushfires. The last extensive wild fires in the area occurred in spring 1967, and summer 2005/6. In the 1860s the small settlement of Moreep was developed at Durdidwarrah, the legacy of which is an area of disturbed secondary vegetation.

In 1979 a large part of the sclerophyll-dominated area was set aside as the Brisbane Ranges National Park although the grassy woodlands near Durdidwarrah were reserved 105 years earlier for the protection for the Geelong water supply and remain a singularly important remnant of a once-widespread vegetation

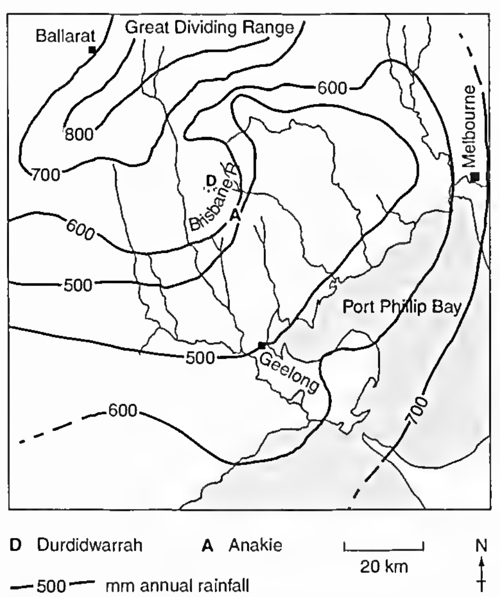

Fig. 1. Map of Melbourne-Geelong-Ballarat region, showing location of Brisbane Ranges, and mean annual rainfall isohyets. Note rain shadow area west of Port Phillip Bay.

type in Western Victoria. The aims of this paper are to (1) describe the composition and distribution of the vegetation, particularly the distribution of sclerophyll and grassy communities in relation to climate, soils and geology, (2) test experimentally plant-soil interactions, and (3) discuss some of the important factors affecting the dynamics of the vegetation. The general area occupies about 100 km^2 and extends 10 km north and west of Anakie (Figure 2). Nomenclature of vascular plants follows the Flora of Victoria (Walsh and Entwisle 1994, 1996, 1999).

Physiography and geology

The main topographic and geological features are mapped in Figures 2 and 3. The salient feature of the area is the scarp of the north-south Rowsley Fault, 150–244 m high (Figure 4), which, with fault apron deposits, defines the western edge of the Port Phillip Sunkland (Hills 1976). Rejuvenated streams have dissected deeply into the scarp exposing the Lower-Middle Ordovician bedrock of strongly folded slates, sandstones and greywackes over a distance of 8–10 km. The southern areas of these rocks around Steiglitz were actively mined for alluvial and reef gold in the late 1800s. The altitude of the plateau terrain increases towards the north and retains a capping of Tertiary (Pliocene) sandy clays on ridges and spurs, which, in the largest contiguous area in the Durdidwarrah region, reaches depths of 10–30 m. These sediments have been lateritized to various extents and ironstone rubble, mottle and kaolinitization are conspicuous near the boundaries and towards the Rowsley Fault. The Brisbane Ranges are defined, both in the east and west, by Quaternary basalt flows and scoria cones.

Numerous swamps occur on flat terrain in the Tertiary capping 6–10 km west of the scarp, two of which were utilized in 1874 as sites for reservoirs of the Geelong Water Supply. Most of the swamps are sandy clay-based and associated with lunettes of sand to sandy loam on the east to south sides, suggesting periods of aridity in late Quaternary times. This is supported by a C^{14} date of 3150 +100 yrs BP at the base of 15 cm of peat at Trotter's Swamp near Durdidwarrah. However the date for such deflation is a minimum since peat requires subsequent vegetation to have developed under waterlogged conditions. In 2003, after several years of drought, the Durdidwarrah reservoirs dried out and hot northerly winds blew sand onto an adjacent lunette vegetated by a woodland of *E. viminalis* and bracken to a depth of 20–30 cm (D.H. Ashton, personal observation). This indicates that the processes of lunette formation can be activated at the present time under exceptional conditions.

White sands occur locally as shallow deposits over the Tertiary material from Durdidwarrah to the east. It has been suggested by Malcolm Wallace (personal communication) that these may represent old shore-line features of the Moorabool Viaduct formation (Bowler 1963) that were redistributed prior to the Pleistocene uplift of the Rowsley Fault. In a few places on the plateau, white sand up to 50 cm deep has filled narrow drainage channels, possibly as a result of wind erosion in a period of aridity when vegetation cover was sufficiently sparse. Some of the complexes of Quaternary deposits and swamps at, and west of, Durdidwarrah have meagre catchments and may be pre-uplift relics of salt marshes at the margins of the old Tertiary shorelines, somewhat analogous to similar features today at Altona and Pt Wilson on the western side of Port Phillip Bay. Stony Creek, Reilly Creek and Little River, which drain the scarp to the east, are associated with variable deposits of colluvium and alluvium 10–100 m wide.

Climate

In general the climate conforms to a modified Mediterranean type (Leeper 1970). At Durdidwarrah in the centre of the study area the average rainfall from 1874–2003 was 688.8 mm with a coefficient of variation of 25.4%. However, since 1922, the decadal variability has increased from about 22% to over 26% (Bureau of Meteorology, unpublished data).The rainfall range over the whole record varies from 52% below to 178% above the mean. The seasonal rainfall distribution is a subdued bimodal type with a maximum in Spring and a minimum in Summer (Figure 5) — the coefficient of variation being least in Spring and greatest in Summer. The mean rainfall in the general area decreases eastward in the lee of the western highlands forming a rain shadow. Thus, from Durdidwarrah to Anakie, an altitudinal decrease of 118 m across the Rowsley Fault is associated with a decrease in mean annual rainfall of 63 mm. The decades of the 1950s and 1970s were wetter than usual (Figure 6). There were very severe droughts in 1967, 1982 and 2001–3 (Bureau of Meteorology, unpublished data).

Annual variation of temperature is not extreme. The mean maximum air temperature at Durdidwarrah

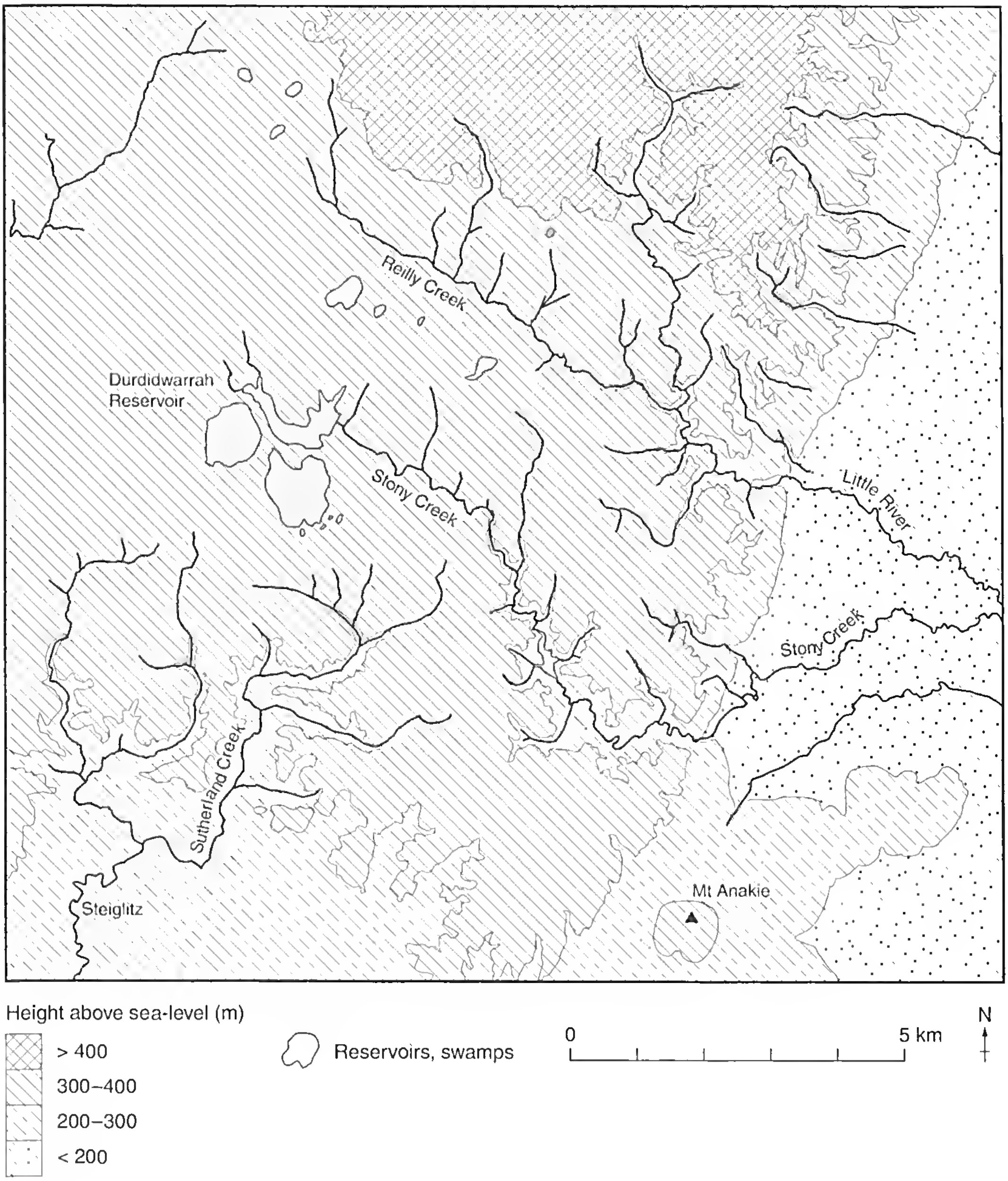

Fig. 2. Map of the broad topography of the Brisbane Ranges area.

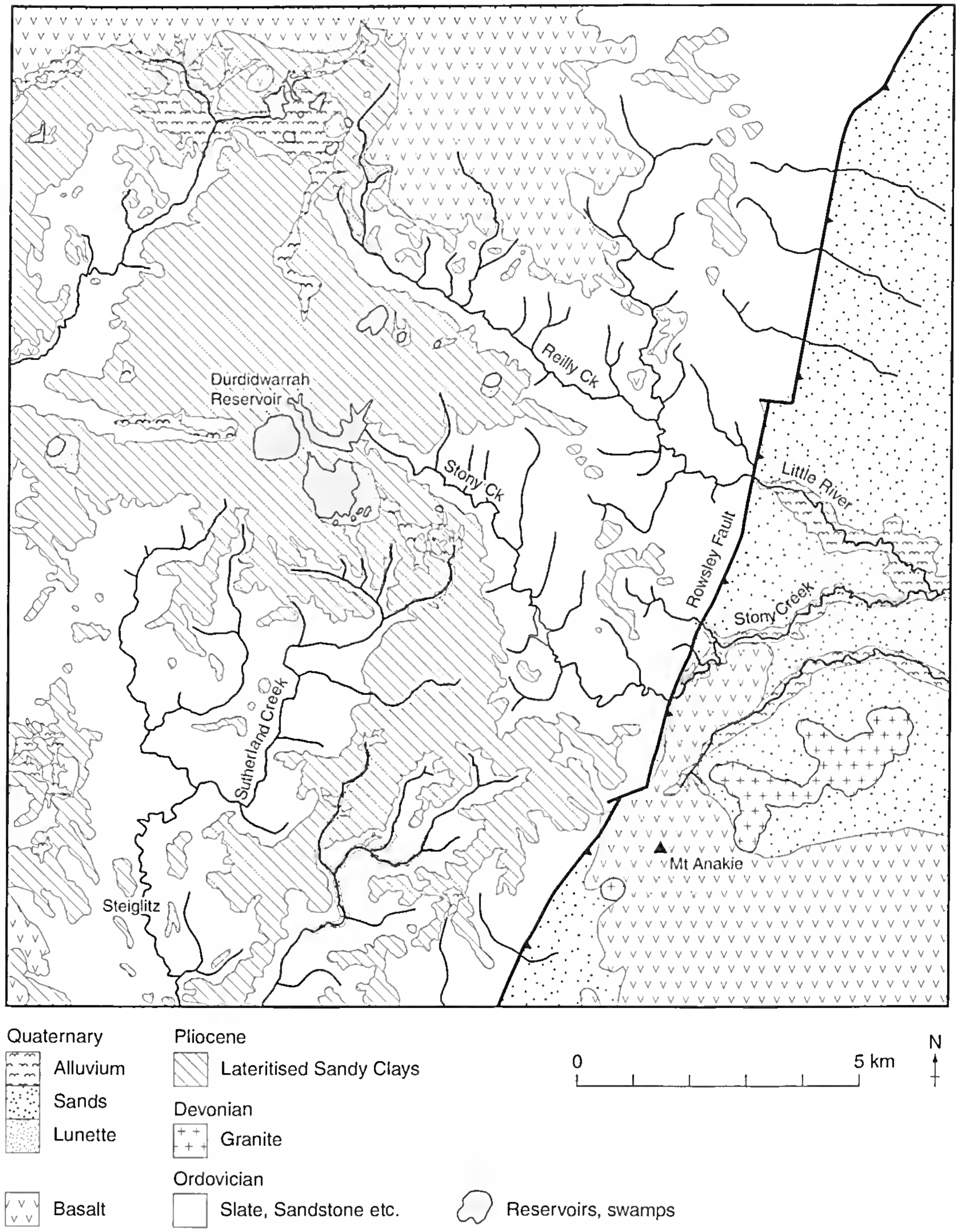

Fig. 3. Generalized map of the geology of the Brisbane Ranges area, from the Geological Survey of Victoria by P.F. Bolger 1980.

Fig. 4. Aerial oblique photograph of the Brisbane Ranges along the Rowsley Fault line, looking south from Balliang approximately 5 km from the northern end of the Ranges. The Brisbane Ranges, to the right of the photograph, are developed on the scarp and upthrown block of the Rowsley Fault. Most slopes are Ordovician sediments, with the flatter ridge tops capped by Tertiary sediments. The lower slopes of the Ranges are mantled by colluvium and alluvial deposits fanning out over the basalts of the Werribee Plains (to the left of the photograph). Photograph: Neville Rosengren, La Trobe University, 1992.

(366 m a.s.l.) is 17°C and the minimum 7.8°C, with an average of 28 days below 2.2°C. Snowfall is rare and evanescent. Winds are predominantly from the NW-SW.

Soils

The soils of the area have been interpreted according to the classificatory schemes of Northcote (1971) and Stace et al. (1968). There is a strong correlation with both geological parent material and topography. The deeper soils (1–2 m) on the gentler slopes of the plateau are leached, solodic and duplex (Dy; *sensu* Northcote 1971). Coarse sandy loam topsoils occur in the east on lateritized Tertiary sandy clays but, further west, soils are finer-textured and hard-setting with a decrease in the ratio of coarse-to-fine sand. This also reflects the grain size spectrum in the parent material at 4–5 m (Figure 7). The sharp boundary at the surface of the sandy clay B horizon is marked by buckshot gravel — a feature

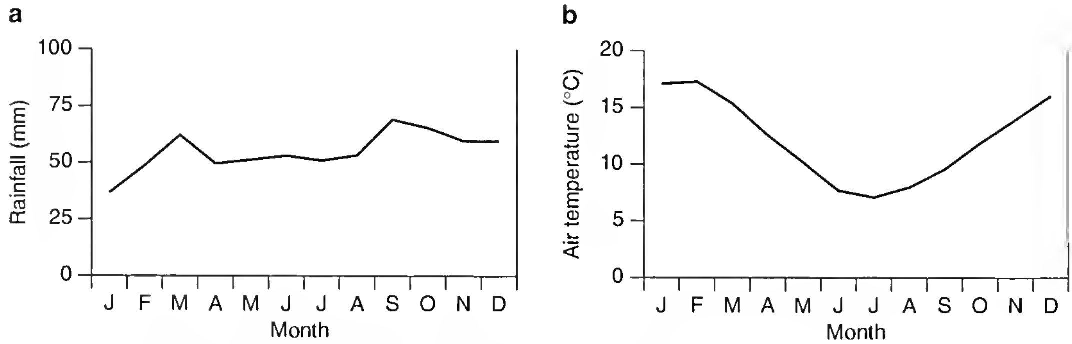

Fig. 5. Mean seasonal rainfall (a) and air temperature (b) for Durdidwarrah.

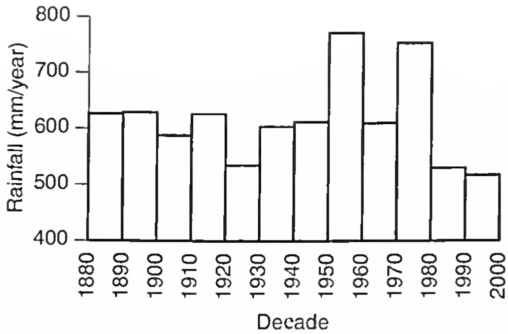

Fig. 6. Long-term variation of decadal rainfall for Durdidwarrah. (Source: Bureau of Meteorology, Melbourne).

indicating recurrent perched water tables in wetter periods (Leeper 1967). In the eastern area, coarse sandy loam over yellow mottled sandy clay predominates, whereas in the area west of Durdidwarrah hard setting, fine sandy loams over yellow mottled clays predominate. In wet years the soils of the latter area are associated with water-logged, plastic A2 horizons. The clayey B horizons grade into lateritized Tertiary material that shows conspicuous yellow, red and white mottle as well as patches of indurated ironstone. In shallow drainage lines in the grassy woodland areas massive sheets of ironstone may occur. In some places fine, grey, indurated silcrete occurs at the base of the lateritic material. At the margins of the Tertiary capping, soils are reddish brown with ironstone present in the profile. It is possible that this soil has developed on laterite exposed by previous denudation.

On flat ridges and plateau areas from which the Tertiary capping has been stripped, Ordovician rocks form the parent material of leached, silty loam, solodic soils which are similar to the fine sandy loams on the Tertiary capping to the west, but much less prone to waterlogging. Reef quartz is common in many profiles and silty clay subsoils contain much fragmented slate (Figure 8). On intricately dissected terrain, soils are generally skeletal and textural variation may be due to the local preponderances of slates, siltstones or sandstones. On both ridge-tops and hot dry aspects with steep slopes, soils are very shallow and rocky whereas, on the cooler south and east slopes, profile differentiation may be minimal and increase in depth downslope due to the accumulation of hillwash and soil creep. Along creeks, small alluvial flats with deeper profiles with humus-rich top soils are associated with heavier, gleyed subsoils near the ground water tables at depths of 1–2 m. On the plateau to the west, lunettes in the lee of swamps show 1–2 m of uniform pale yellow to buff sands and loamy sands over orange-brown loams or clay loams. In a few places, such as near Durdidwarrah, white sands occur with older humus podsol soil profiles and coffee rock B horizons.

DISTRIBUTION AND COMPOSITION OF THE VEGETATION

In order to quantitatively study the floristic composition of the major vegetation types, and the relationships between floristics, soil types and topography, we undertook a quadrat survey, with quadrat data then subjected to multivariate analysis. A grid of 62 quadrat sites was established over an area of about 55 km^2, with quadrats located at ca. 0.8 km (half mile) intersections using the Meredith contour Military Map (scale 1:63,360) from 1967–1972. Each quadrat was 6 m radius, and within each quadrat the cover of all plant species was assessed using the Braun-Blanquet ordinal scale (Kershaw 1966). Soil profiles were described from auger holes in the centre of each quadrat together with slope, aspect and geology. The floristic data (presence/absence) were subjected to hierarchical, polythetic, agglomerative classification and principal coordinates ordination (Lance and Williams 1968).

The multivariate analyses indicated that there were several main vegetation complexes associated with geology, soils and topography (Figures 9, 10). The primary distinction, as shown by the classification and supported by the ordination, was between open-forests variously dominated by *E. macrorhyncha* , with an understorey of sclerophyllous shrubs (hereafter 'sclerophyll open-forest'; Figure 11), and woodlands variously dominated by *Eucalyptus viminalis* and *E. ovata*, with grassy understoreys (hereafter 'grassy woodlands'; Figure 12). There are ecotones between these two primary vegetation types, as indicated by the ordination (Figure 10), which may be diffuse or sharp, and may occur over a distance of a several hundred metres. The three main types, with the most extensive distribution (Figure 13), are:

1. Forests/woodlands of *Eucalyptus obliqua- E. macrorhyncha* with an understorey of sclerophyllous shrubs, on coarse sandy loams on the Tertiary capping in the east-south east.

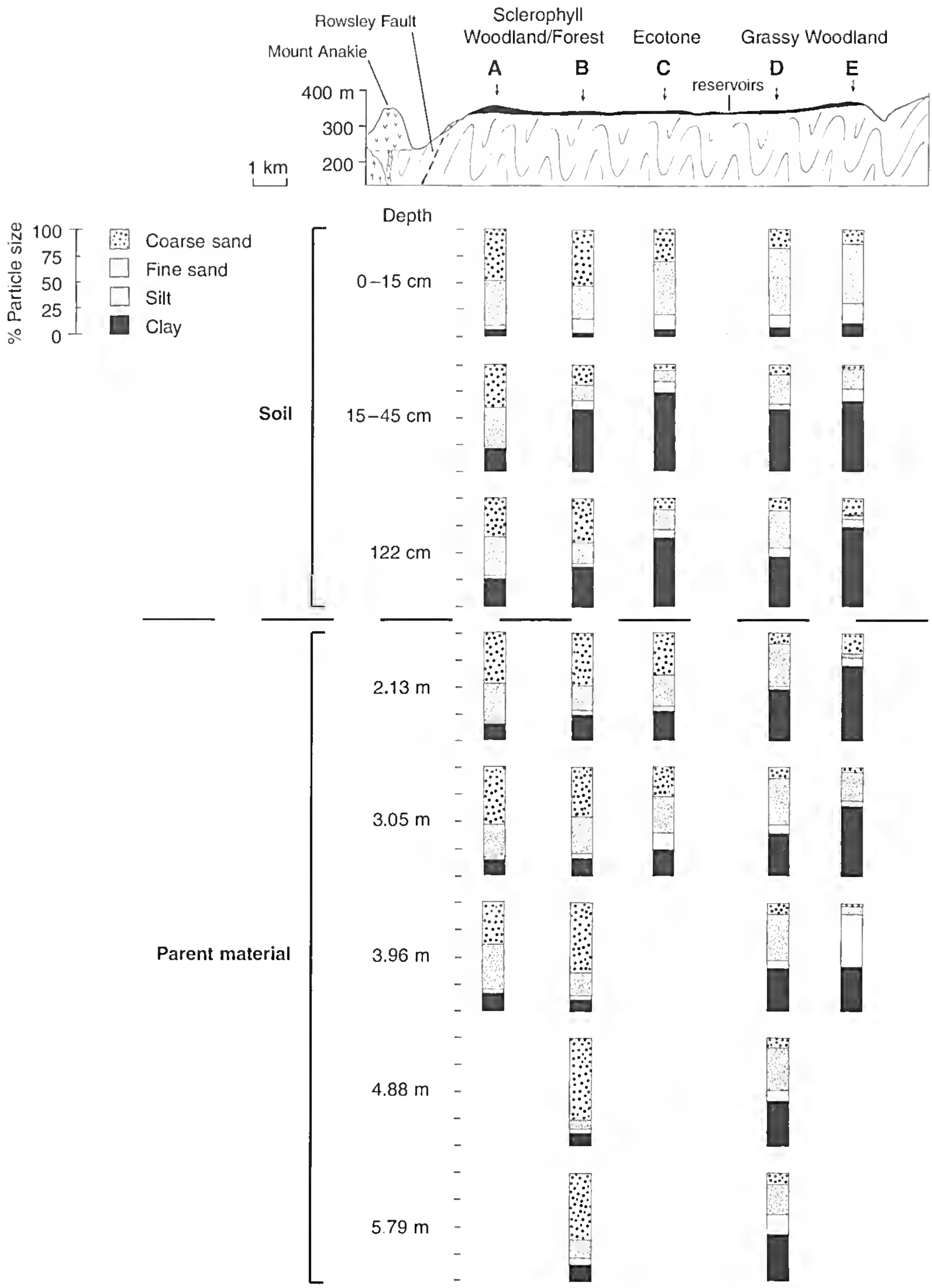

Fig. 7. Particle size composition (%) in soil profiles and parent material from bore holes from east (left) to west (right) across the Tertiary plateau. A-E indicate approximate locations of bore holes along a broad transect NW from Mt Anakie, where floristic quadrats were located (see Table 1).

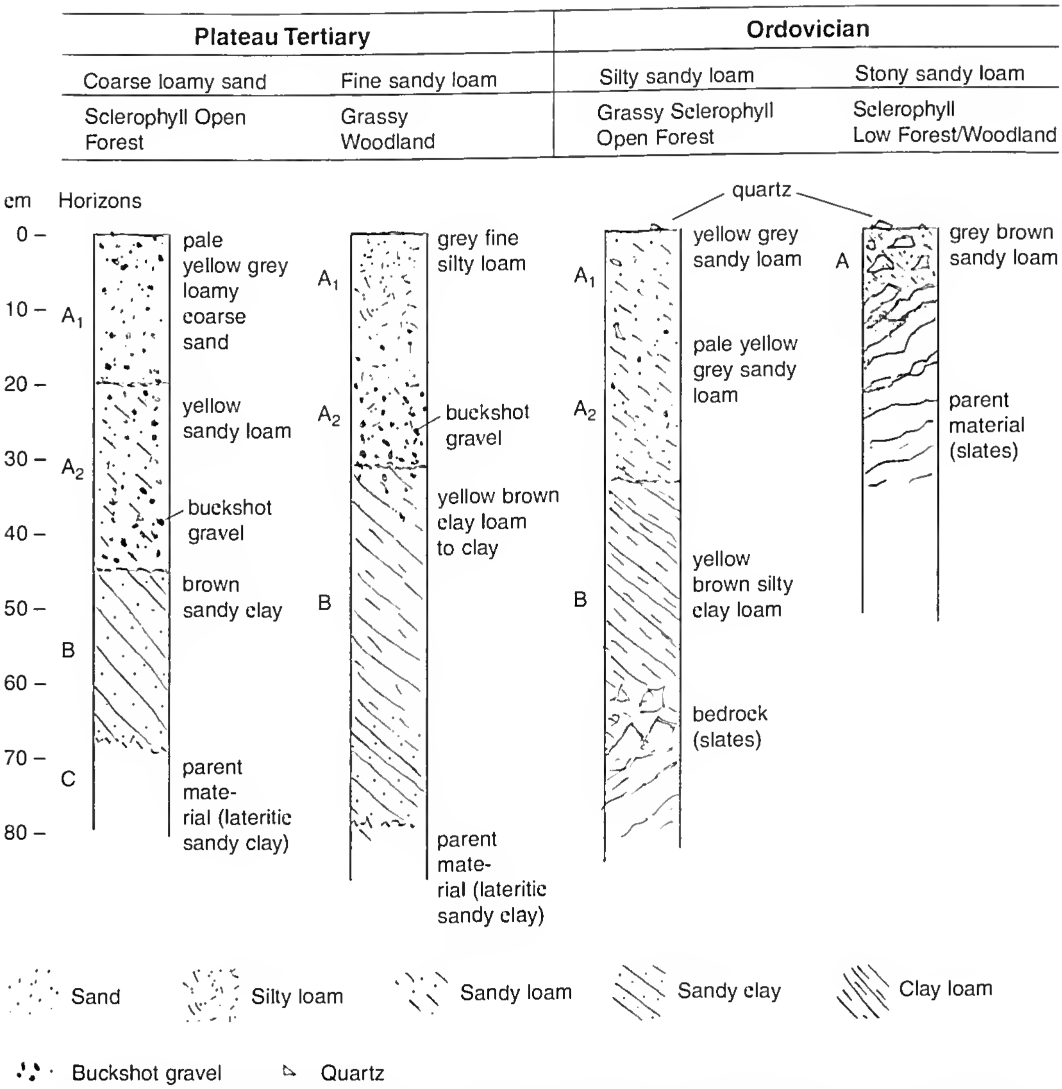

Fig. 8. Profiles of yellow solodic soils from sclerophyll open forest and grassy woodland on the Tertiary plateau and sclerophyll forests on Ordovician bedrock.

2 Woodlands dominated by *E.viminalis* , *E. ovata* and *E. pauciflora* with a grassy understorey , on the fine sandy loam solodic soils of the Tertiary capping in the west–north west.

3. A complex of woodlands and forests, generally dominated by *Eucalyptus macrorhyncha,* on the dissected Ordovician terrain; *E. macrorhyncha* may be associated with up to 8 of the 12 other eucalypts present in the area.

The multivariate analyses also identified several additional minor complexes, with relatively restricted distributions, such as woodlands associated with the sandy lunettes and forests associated with gullies (Figures 9 and 10).

The five major complexes are mapped in Figure 13. The broad nature of the floristic variation across the plateau from east to west, from sclerophyllous forest, through ecotonal vegetation, to the grassy woodlands (as sampled from multiple quadrats at each of points A-E in Figure 7) is presented in Table 1. Detailed descriptions of the vegetation complexes, in relation to geology, topography and soils, are given below.

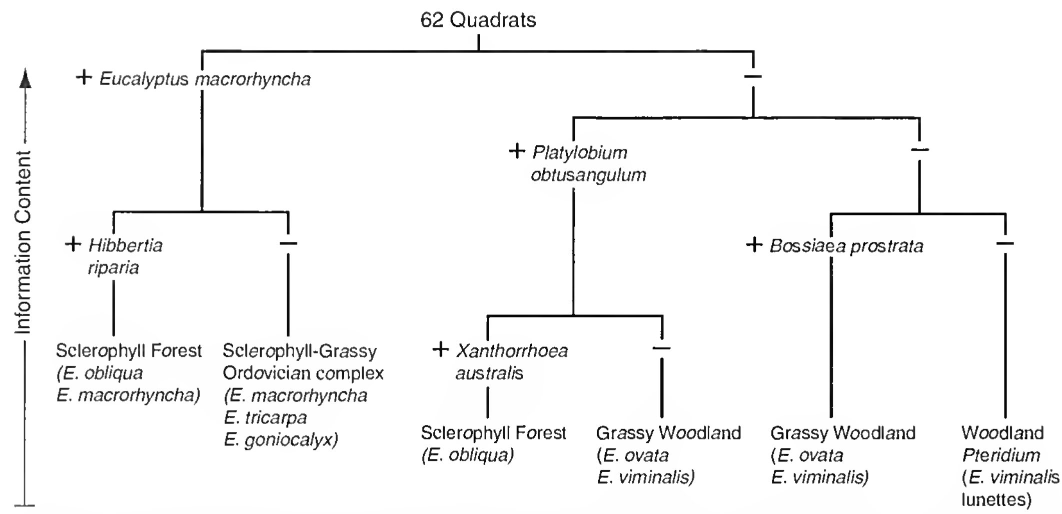

Fig. 9. Hierarchical, agglomerative, polythetic classification of floristic quadrats. Positive and negative symbols indicate presence or absence of key listed species between groupings. Dominant species and vegetation structure indicated at the base of each arm of the dendrogram.

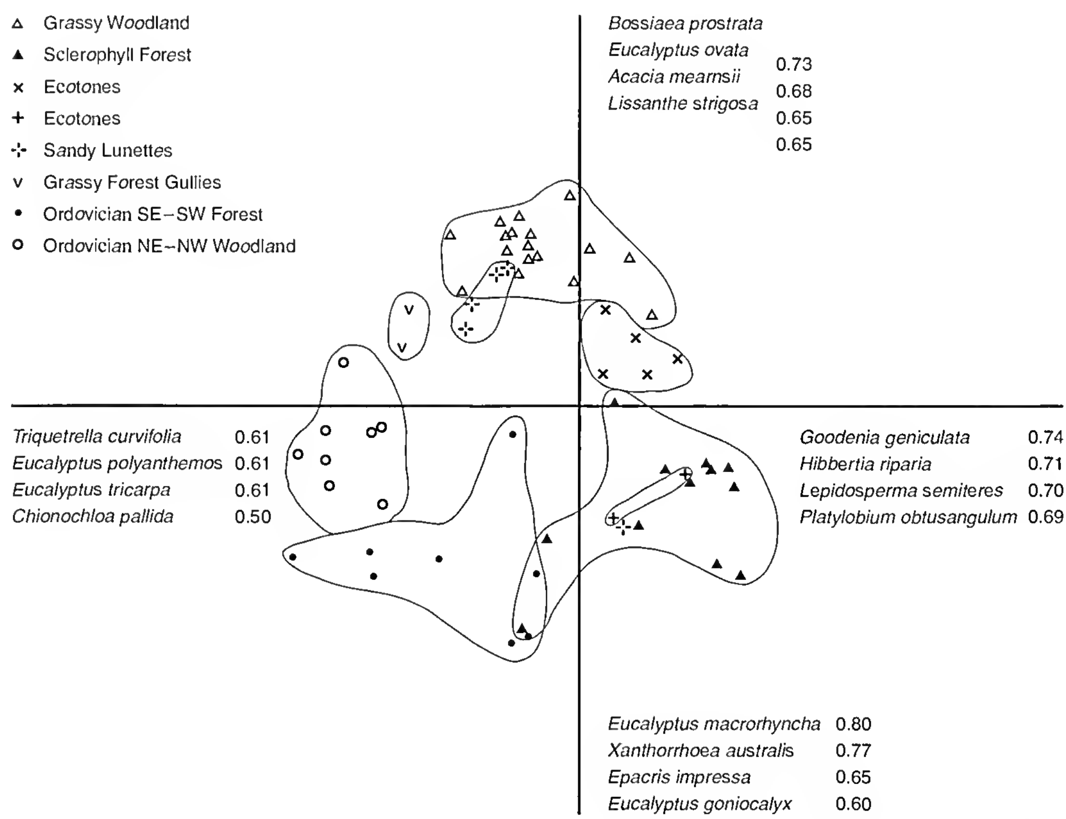

Fig. 10. Principal coordinates ordination of floristic quadrats. Species with the highest correlation coefficients with each direction of the two axes of the ordination are indicated.

Fig. 11. Open forest variously dominated by *E. macrorhyncha* , with shrubby understorey of *Epacris impressa, Acacia pycnantha* and *Xanthorrhoea australis*. Location near Boar Gully. Photograph: James Shannon, La Trobe University, August 2006.

Fig. 12. Woodland variously dominated by *Eucalyptus viminalis* and *E. ovata*, with a grassy understorey. Location: south-west of Durdidwarrah. Photograph: James Shannon, La Trobe University, August 2006.

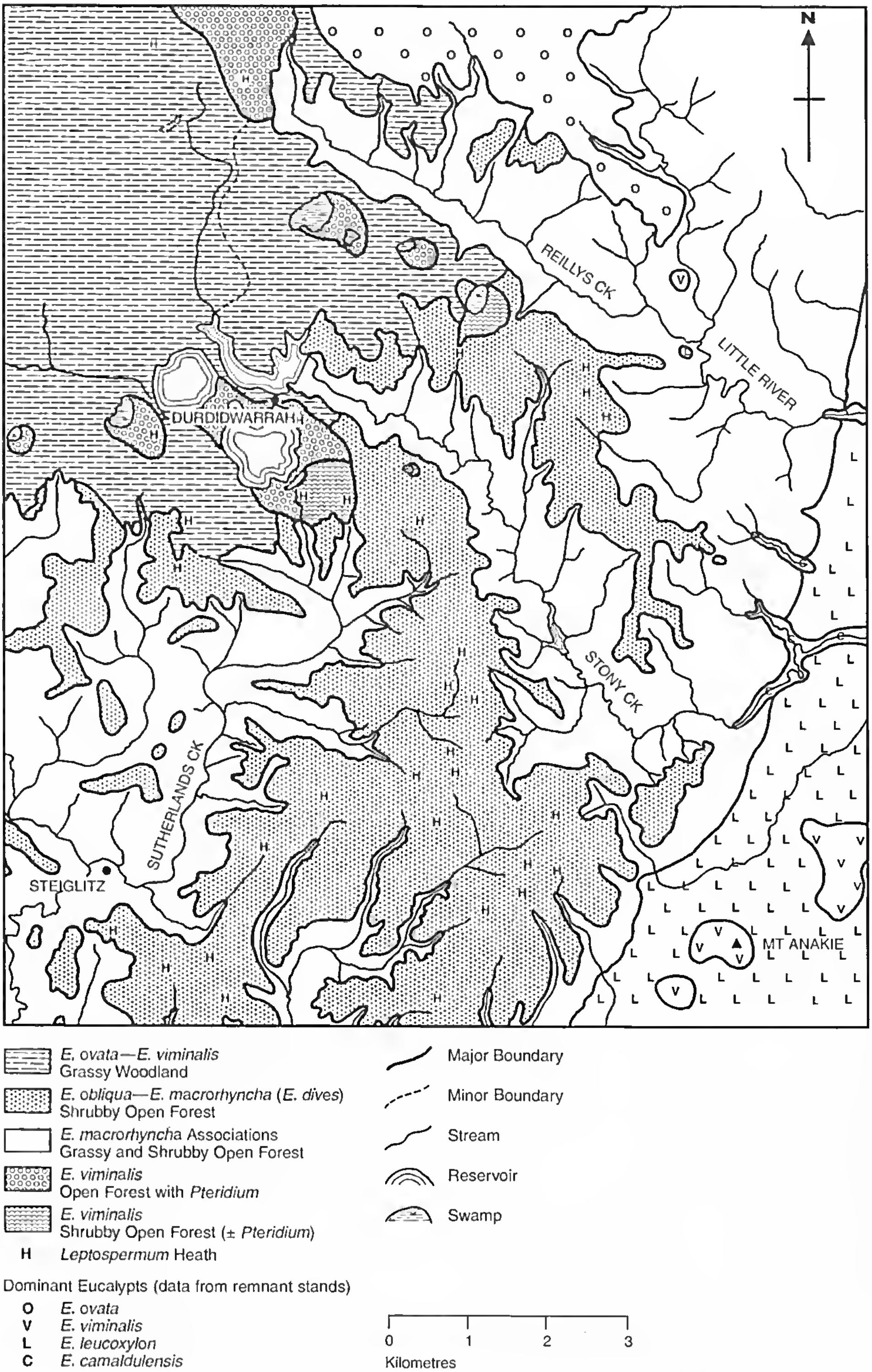

Fig. 13. Vegetation map of main structural vegetation types in the Brisbane Ranges study area. E = *Eucalyptus*.

	A	B	C	D	E
	Dry sclerophyll forest		Ecotone	Grassy Woodland	
Trees:					
Eucalyptus baxteri	24	.	.	.	.
E. aromaphloia	32	16	.	.	.
E. macrorhyncha	8	20	.	.	.
E. obliqua	20	48	20	.	.
E. radiata	.	.	4	.	.
E. pauciflora	.	.	.	36	.
E. viminalis	.	.	8	12	.
E. ovata	.	.	40	24	48
Shrubs, small trees:					
Aotus ericoides	4	.	.	.	.
Correa reflexa	8	.	.	.	.
Platylobium obtusangulum	8	.	.	.	.
Monotoca scoparia	12	.	.	.	.
Lomatia ilicifolia	4	.	.	.	.
Leptospermum myrsinoides	8	.	4	.	.
Xanthorrhoea australis	32	36	16	.	.
Hibbertia riparia	.	4	.	.	.
Isopogon ceratophyllus	.	8	.	.	.
Banksia marginata	.	16	.	.	.
Leptospermum continentale	.	4	.	.	.
Astroloma humifusum	.	.	4	.	.
Acrotriche serrulata	.	.	4	20	.
Lissanthe strigosa	.	.	4	.	.
Allocasuarina littoralis	.	.	8	.	.
Exocarpos cupressiformis	.	4	.	.	.
Acacia mearnsii	4	12	8	.	.
A. melanoxylon	.	4	.	.	.
Bossiaea prostrata	8	12	.	.	.
Herbs:	.	.	.	.	.
Dicotyledons:	.	.	.	.	.
Gonocarpus tetragynus	.	.	.	.	4
Leptorhynchos tenuifolius	.	.	.	.	8
Dichondra repens	.	.	.	.	16
Monocotyledons:					
Lepidosperma semiteres	4	40	.	.	.
Lepidosperma laterale	.	.	4	.	.
Austrodanthonia setacea	.	4	.	.	.
Austrodanthonia geniculata	.	.	8	8	.
Dichelachne micrantha	.	4	.	.	.
Austrodanthonia eriantha	.	.	4	12	.
Schoenus apogon	.	.	4	.	24
Arthropodium strictus	.	.	8	.	4
Anthoxanthum odoratum	.	.	.	12	.
Austrostipa semibarbata	.	.	12	.	8
S. pubinodis	.	.	4	.	44
S. nervosa	.	.	4	12	8
Poa sieberiana	.	.	8	40	72
Themeda triandra	.	.	16	16	24
Austrodanthonia laevis	.	.	.	4	24
Austrodanthonia racemosa	.	.	.	4	8
Austrodanthonia caespitosa	.	.	.	.	4
Dianella revoluta	.	.	.	.	4
Bryophytes:					
Rhynchostegium tenuifolium	.	.	4	4	.
Hypnum cupressiforme	.	.	44	68	4
Thuidium furfurosum	.	.	.	8	16
Campylopus introflexus	.	.	.	.	4
Triquetrella curvifolia	.	.	.	.	4

Table 1. Percent frequency of species with cover values > 25% at five bore sites (A-E) from sclerophyll forest near Rowsley Fault (A, East) to grassy woodland near Durdidwarrah (E, West; Figure 7) in 1970. 25 quadrats, each $1 m^2$, were sampled at each of the five locations.

Plateau Terrain

1. Vegetation on the Tertiary sandy clays

a) *E.obliqua-E.macrorhyncha* sclerophyll open-forest on coarse sandy loam solodic soils

The tree stratum of these stringybark species reaches about 25 m having an average canopy cover value of 62%. On the structural classification of vegetation by Specht (1970), it conforms to Open-Forest. Treeless heathland areas exceeding 0.5–1 ha in area may occur within the open-forest. A general thinning out of trees has also occurred due to dieback caused by the root fungus *Phytopthora cinnamomi* (Weste and Ashton 1994).

E. obliqua is the most common tree species and is associated occasionally with *E. aromaphloia*, *E. goniocalyx* or *E. baxteri*. The shrub understorey, 0.5–2 m tall, consists of a mixture of sclerophyllous shrub species — *Hakea decurrens, Platylobium obtusangulum, Hibbertia riparia, Leucopogon ericoides, Acacia myrtifolia, A. pycnantha, Grevillea chrysophaea, Banksia marginata* (shrub form) and *Isopogon ceratophyllus* — and the arborescent monocotyledon *Xanthorrhoea australis*. The ground stratum is generally dominated by sedges (*Lepidosperma semiteres, L. laterale* and *Gahnia radula*), together with scattered grasses (*Austrodanthonia setacea, Austrostipa semibarbata, Tetrarrhena distichophylla, Amphipogon strictus)*, lilies *(Burchardia umbellata, Thysanotus patersonii)* and orchids *(Caladenia carnea* and *Glossodia major*; Table 2). Advanced lignotuberous regeneration of eucalypts, 0.5–2 m high, occurs sporadically in some canopy gaps (Figure 14). In the sclerophyll open-forest community the commonest large herbivore browsing woody plants is the Black-tailed wallaby (*Wallabia bicolor*). The cratered ant nests of *Aphaenogaster longiceps* are very common and may be important in soil aeration and water infiltration to lower levels in the soil profile as has been shown for the closely related *A. barbigula* in semi-arid Australia by Eldridge (1993).

Along shallow drainage lines in this general community, trees are sparse and a tall sclerophyllous shrub stratum is dominated by dense *Leptospermum continentale, Melaleuca ericifolia* and *Hakea rostrata* with a ground stratum of *Lepidosperma laterale, Gahnia sieberiana, Lindsaea linearis,* and *Tetrarrhena juncea.* These areas may be associated with heavy clay sub-soils or accumulations of infilling white sand.

b) *E. ovata, E.viminalis* and *E. pauciflora* grassy woodland on fine sandy loam solodic soils

The tree stratum is 15–20m high, with crown cover values of 30% (Figure 15) and is therefore a woodland according to Specht (1970). Along gentle slopes with a 2–3° gradient, the dominance of eucalypts changes from *E. ovata* in the moister, more waterlogged sites down slope through *E. viminalis* on intermediate sites to *E. pauciflora* on slightly elevated areas In some of the latter sites, small patches of *E. radiata* and *E. obliqua* may also occur. A scattered, small tree stratum of *Acacia melanoxylon* and *A. mearnsii*, 3–4 m tall, is usually present above a ground layer of grasses such as *Austrodanthonia procera, A. eriantha, Austrostipa pubescens, Microlaena stipoides* and *Themeda triandra*. Conspicuous geophytes in spring include *Bulbine bulbosa, Arthropodium strictus, Hypoxis glabella* and *Wurmbea dioica,* as well as numerous orchids. Low scattered shrubs, such as *Lissanthe strigosa, Platylobium obtusangulum, Hibbertia riparia* and *Bossiaea heterophylla,* occur mainly in better drained sites (Table 2). The stunted lignotuberous regeneration of the major eucalypts is not browsed in this grassy woodland.

In various sites in this community, dense patches of scrub 25–50 m in diameter and 4–9 m tall are dominated by *Allocasuarina littoralis, Banksia marginata* (small tree form) and *Acacia mearnsii* and are sometimes associated with dead eucalypts (Figure 16). Some patches may be sufficiently large to warrant the structural term, layered woodland (Specht 1970).

The predominant native herbivores in this community are Eastern Grey kangaroos *(Macropus giganteus*). Eucalypt canopies are often severely browsed by koalas (*Phascolarctos cinereus*).

c) *E. viminalis* woodlands on lunettes and swamps

There are seven or eight lunettes scattered to the north and west of Durdidwarrah on the fine sandy clay areas of the Tertiary capping. The lunettes occur to the south and east of swamps and are low, diffuse dunes of sand to loamy sand vegetated by woodland of *E.viminalis*. Undergrowth is commonly dominated by dense bracken but areas of light grass (*Austrodanthonia setacea*, *Vulpia bromoides*), forbs and scattered shrubs (*Acrotriche serrulata, Astroloma humifusum, Hibbertia riparia*) also occur. On the white sand podsol soils near Durdidwarrah, *Xanthorrhoea australis* may form dense understoreys and include many sclerophyll shrubs (*Leptospermum myrsinoides, Leucopogon virgatus)* characteristic of sclerophyll forest communities to the south and east.

Swamp communities vary greatly depending on the permanence and depth of water. In deeper

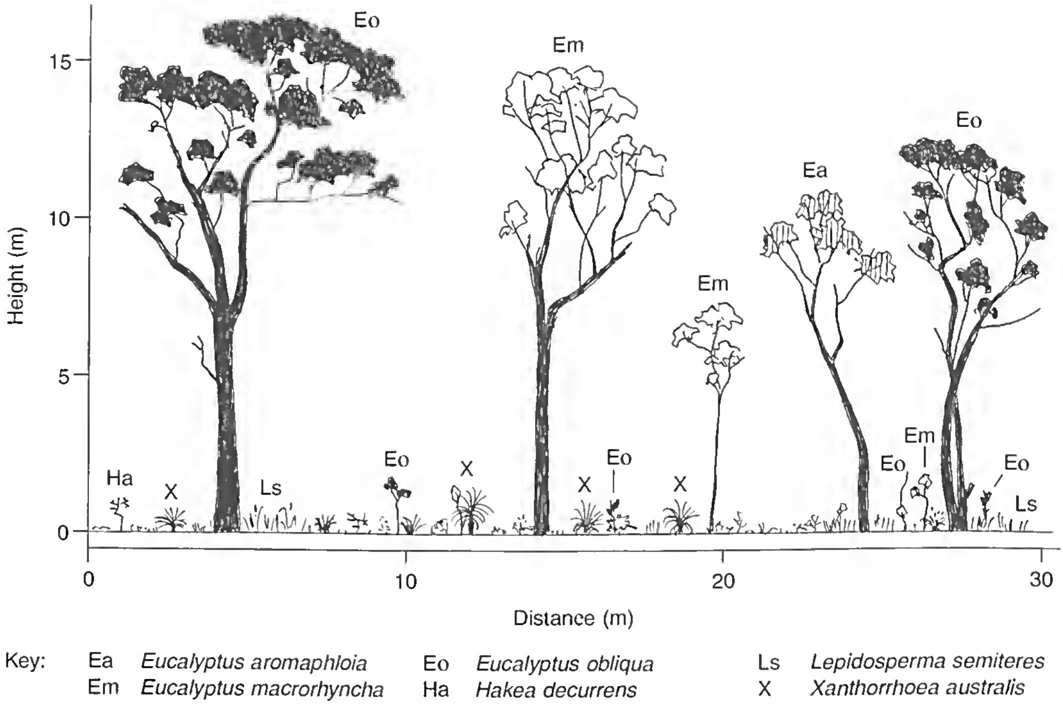

Fig. 14. Vegetation profile of typical sclerophyll open-forest dominated by *Eucalyptus obliqua, E. macrorhyncha, E. aromaphloia.*

swamps, open-sedgelands of *Eleocharis sphacelata, Typha muelleri* and *Phragmites australis* are associated with hydrophytes such as *Myriophyllum propinquum, Limnanthemum crenatum* and *Villarsia exaltata.* In shallower swamps, swamp margins and swampy drainage lines, closed sedgelands of *Baumea rubiginosa, Carex appressa* and *Lepidosperma longitudinale* may be associated with *Poa labillardieri, Centella cordifolia, Juncus australis, Geranium solanderi, Acaena novae-zelandiae, Senecio glomeratus, S. biserratus* and *Austrodanthonia semiannularis.* Some of these communities may grade locally into the grassy woodlands dominated by *E. ovata* and *E. viminalis.*

2. Vegetation on Ordovician bedrock

Open-forests and woodlands of *E. obliqua, E. macrorhyncha, E. tricarpa, E. dives* and *E. radiata* on leached, hard-setting silty loam solodic soils

This variable community is of similar stature to the sclerophyll forests to the south-west, but has many features of the grassy woodlands. The shrub stratum is moderate to open and consists of *Acacia pycnantha, Pultenaea daphnoides, Correa reflexa* and *Epacris impressa* and the field layer is dominated by *Chionochloa pallida*, often with dense carpets of *Pultenaea pedunculata.* Stands of *Xanthorrhoea australis* have been locally common but are now severely depleted due to the Cinnamon fungus (*Phytophthora cinnamomi*). A comparison of floristics on Tertiary and Ordovician parent material on the plateau interfluve between Reilly Ck and Stony Ck in 2005 is shown in Table 3. Total floristic similarity (i.e. the number of species in common as a percentage of total number of species in both areas) is 36.8%. *Chionochloa pallida* is characteristic of the Ordovician, and *Hibbertia riparia* of the Tertiary capping areas.

Dissected Terrain

1) Vegetation of Ordovician bedrock slopes and ridges

The vegetation of these habitats is very complex and varies from open-forest, 25 m tall, with grassy and sclerophyll understoreys on gradational soils of south-east slopes to low multi-stemmed sclerophyll woodland on skeletal rocky soils of hot dry ridge tops. It is dominated by up to seven species of eucalypt and varies floristically from south to north.

	Dry Sclerophyll Forest/Woodland N=46	Grassy Woodland N=36
Trees:		
Eucalyptus obliqua	61	0
E. macrorhyncha	26	0
E. aromaphloia	11	8
E. pauciflora	0	8
E. viminalis	0	8
E. ovata	0	25
Shrubs:		
Platylobium obtusangulum	93	
Hibbertia riparia	80	
Xanthorrhoea australis	65	
Pultenaea humilis	59	
Banksia marginata	54	
Leucopogon virgatus	43	
Correa reflexa	37	
Hovea linearis	37	
Hakea decurrens	33	
Tetratheca ciliata	30	
Acacia myrtifolia	28	
Sphaerolobium vimineum	28	
Pimelea humilis	26	3
Acrotriche serrulata	15	50
Gompholobium huegelii	17	
Grevillea australis	11	
Lomatia ilicifolia	9	
Grevillea chrysophaea	6	
Persoonia juniperina	2	
Hardenbergia violacea	2	
Comesperma volubile	4	
Acacia brownii	2	
Monotoca scoparia	2	
Astroloma humifusum		7
Dillwynia glaberrima		8
Acacia melanoxylon		3
Exocarpos cupressiformis		3
Dillwynia cinerascens		3
Lissanthe strigosa		19
Acacia mearnsii		28
Kennedia prostrata	2	50
Bossiaea prostrata	4	72
Herbs:		
Dicotyledons:		
Gonocarpus tetragynus	46	
Opercularia varia	50	
Drosera auriculata	41	3
Drosera whittakeri	37	11
Goodenia geniculata	33	
Pimelea humilis	26	3
Leptorhynchos squamatus		6
Rumex brownii		3
Cirsium lanceolatum		3
Moenchia erecta		3
Cymbonotus preissianus		3
Swainsona muelleri		3
Cerastium glomeratum		3
Sonchus oleraceus		3
Haloragis heterophylla		5
Helichrysum scorpioides		8
Brachyscome decipiens		8
Pseudognaphalium luteo album		8
Daucus glochidiatus		11
Veronica gracilis		11
Acaena ovina		17
Stylidium graminifolium		17
Geranium solanderi		19
Ajuga australis		25
Dichondra repens		25
Hypericum gramineum		30
Leptorhynchos tenuifolius		33
Asperula scoparia		35
Hypochoeris radicata		36
Oxalis corniculatus		42
Centaurium minus		44
Hydrocotyle laxiflora		53
Poranthera microphylla		64
Monocotyledons:		
Lepidosperma semiteres	87	
Poa sieberiana	72	30
Austrodanthonia setacea	46	
Laxmannia gracilis	35	
Lomandra filiformis	26	14
Amphibromus strictus	22	
Tetrarrhena distichophylla	17	
Burchardia umbellata	17	
Carex inversa	1	
Chamaescilla corymbosa	9	
Dichelachne micrantha	8	
Pterostylis longifolia	8	
Thysanotus patersonii	3	
Dianella revoluta	4	
Lepidosperma laterale	4	
Microlaena stipoides	2	42
Austrodanthonia eriantha	6	5
Austrodanthonia pilosa		2
Austrostipa rudis		25
Pentapogon quadrifidus		17
Tricoryne elatior		10
Cryptogams:		
Campylopus introflexus		8
Breutelia affinis	13	
Cladia aggregata	2	5
Chaetophyllopsis whiteleggei	24	
Bryum sp	5	2
Cladia fimbriata	4	3
Polytrichum juniperinum	4	11
Hypnum cupressiforme	2	22
Lophocolea heterophylloides	2	11
Tayloria octoblephara		5

Table 2. Percentage frequency of species in a series of $1m^2$ quadrats along a bisect from Anakie to Durdidwarrah on the Tertiary capping plateau in 1963, prior to the *Phytophthora cinnamomi* epidemic.

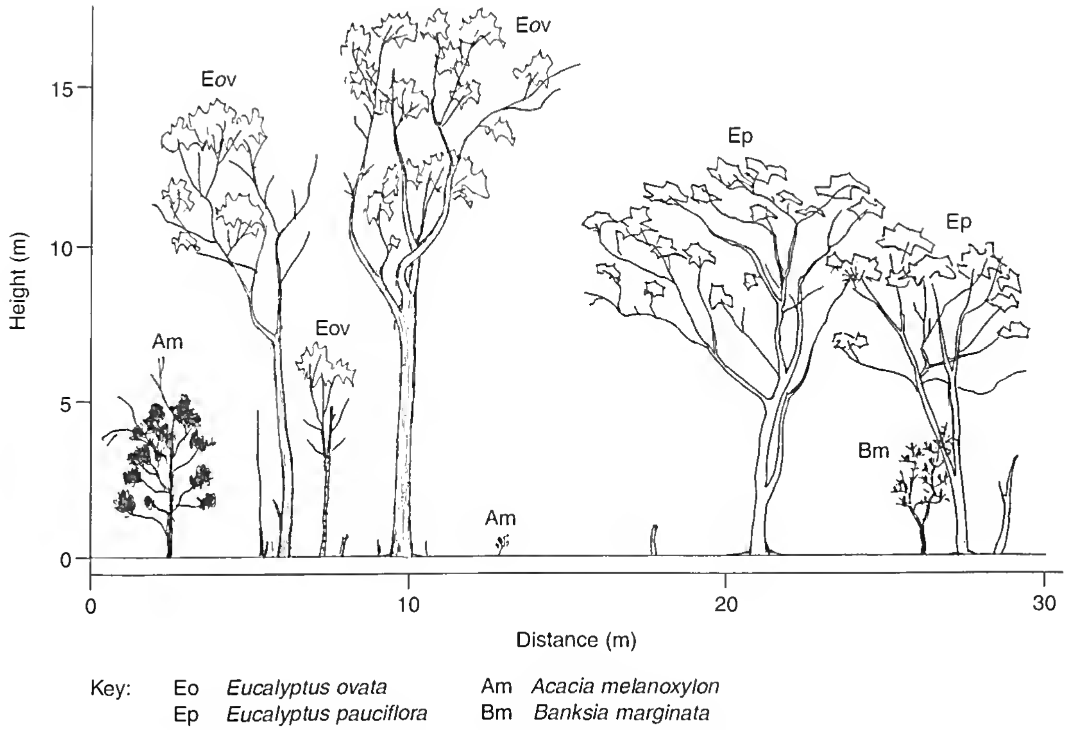

Fig. 15. Vegetation profile of grassy woodland dominated by *Eucalyptus ovata and E. pauciflora.* Species as indicated in the legend.

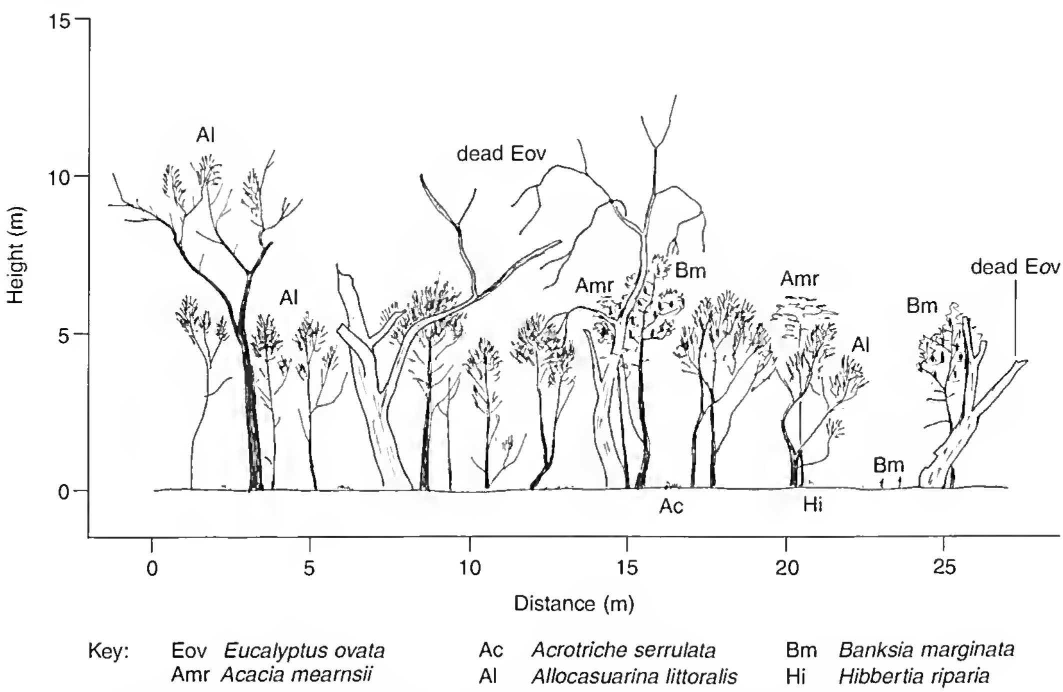

Fig. 16. Vegetation profile of dense scrub patches of *Allocasuarina littoralis* associated with dead eucalypts.

	Tertiary Capping	Ordovician Bedrock
Basal Areas m²/ha		
Trees only:		
Eucalyptus obliqua	28.8	4.1
E. macrorhyncha	22.7	29.1
E. aromaphloia	8.2	2.0
E. goniocalyx	2.0	12.4
E. tricarpa	0	10.3
E. dives	4.1	10.3
Frequency/5 quadrats		
Trees:		
E. obliqua	5 (4)	1 (1)
E. macrorhyncha	3 (2)	5 (3)
E. aromaphloia	1	0
E. goniocalyx	2	3 (2)
E. tricarpa	1	2
E. dives	1	2 (1)
	n = 6	n = 5
Shrubs:		
Platylobium obtusangulum	5 (1)	0
Pultenaea humilis	4 (1)	0
Correa reflexa	3	0
Pultenaea daphnoides	2	0
Astroloma humifusum	2	0
Isopogon ceratophyllus	1	0
Leptospermum continentale	1	0
Acacia gunnii	1	0
Banksia marginata	1	0
Xanthorrhoea australis	2	2
Spyridium parvifolium	1	0
Acacia pycnantha	4	3
Pultenaea pedunculata	3 (3)	3 (2)
Hibbertia riparia	4	1
Acrotriche serrulata	4	2
Monotoca scoparia	2	3
Pimelea humilis	2	3
Dillwynia sericea	2	4
Pomaderris ferruginea	1	1
Tetratheca ericifolia	1	2
Grevillea steiglitziana	1	3
Hovea linearis	3	1
Leptospermum myrsinoides	1	1
Gompholobium huegelii	2	1
Epacris impressa	0	5
Acacia acinacea	0	1
Acacia aculeatissima	0	1
Daviesia leptophylla	0	1
	n = 24	n = 18
Herbs:		
Monocotyledon:		
Lepidosperma semiteres	5 (3)	1
Lomandra filiformis	5	1
Austrodanthonia setacea	2	0
Austrostipa pubinodis	5	0
Microlaena stipoides	5	0
Deyeuxia densa	1	0
Dichelachne micrantha	4	4
Dianella revoluta	5	3
Thysanotus patersonii	1	1
Gahnia radula	1	3 (1)
Chionochloa pallida	0	5 (5)
Lepidosperma laterale	1	4
Burchardia umbellata	1	0
	n = 11	n = 8
Dicotyledon:		
Goodenia geniculata	4	
Helichrysum rutidolepis	4	1
Opercularia varia	2	0
Gonocarpus tetragynus	4	4
Brachyscome multifida	2	1
Argentipallium obtusifolium	1	0
Brunonia australis	1	0
Hydrocotyle laxiflora	1	0
Rhytidosporum procumbens	0	2
	n = 8	n = 4
Cryptogams:		
Cladia aggregata	3	4 (1)
Cladia retipora	0	1
Campylopus introflexus	2	1
Hypnum cupressiforme	0	1
Dicranoloma menziesii	0	1
	n = 2	n = 5
Total vascular spp.	Grand Total = 49	Grand Total = 35

Table 3. Comparison of vegetation structure and floristic composition between forest on Tertiary capping and Ordovician bedrock. Plateau terrain (McLeods Road). Five quadrats, each of 6 m radius, sampled in January 2005. Tree basal area determined by variable radius method. Figures in parentheses are frequency of occurrence of cover values equal to or greater than 20%. N = number of species.

Eucalyptus macrorhyncha is the most widespread species in this terrain. The vegetation complex should be regarded as a multi-dimensional continuum (Ashton 1976) varying with every nuance of aspect and slope (and perhaps lithology), but for the sake of simplicity it will be described in terms of the major habitats and the most commonly encountered communities. The area north of Reilly Ck has been described phytosociologically by Bridgewater (1976) as containing associations such as Xanthorrhoeo-Platylobietum (*i.e.* mostly *E. baxteri* forest) and Eucalypto-Acacietum pycnanthae (i.e. mostly variants of *E. macrorhyncha* woodlands/forests).

a) Low forest/woodland of *E. dives* with *E. macrorhyncha* on ridge tops and north aspects. This vegetation occurs on rocky quartz sandstone soil on Ordovician bedrock or remnant laterite of the Tertiary capping. Trees may be 4–5 m tall and multi-stemmed and associated with sclerophyll shrubs (*Grevillea steiglitziana, Lomatia ilicifolia*) and *Xanthorrhoea australis*. Lichens are common on bare soil and exposed rock.

b) Woodland of *E.macrorhyncha* and. *E. polyanthemos* (also includes *E. baueriana*).

This vegetation is 10–15 m tall on steep northern to north eastern slopes with skeletal soils. Sclerophyll shrubs are common (*Acacia aspera, Cryptandra amara*) with ephemerals *(Calandrinia calyptrata, Hydrocotyle callicarpa, Aira caryophyllea, Vulpia bromoides).* Lichens are common on bare *soil (Heterodea muelleri, Cladia aggregata, C. retepora)* or exposed rock *(Parmelia conspersa, P. pulla).* On sandstone-rich areas, *Xanthorrhoea australis* may be dominant.

c) Woodland of *E. macrorhyncha* and *E.tricarpa*

This vegetation is 10–15 m tall on moderate west to north western slopes on rocky silty loam soils. *E. tricarpa* predominates on the drier sites. The understorey consists of relatively sparse *Chionochloa pallida* tussocks, and sclerophyll shrubs (*Platysace lanceolata, Prostanthera nivea*) although carpets of *Pultenaea pedunculata* and many ephemeral forbs and grasses may be frequent.

d) Open-forest and woodland of *E. macrorhyncha* and *E. goniocalyx*

This vegetation is found on moderately steep east and southerly slopes with rocky, silty loam soils, with E. *goniocalyx* more common on the cooler, moister aspects. The understorey may consist of *Chionochloa pallida* and *Xanthorrhoea australis* and occasional shrubs, but on the cooler slopes these may be replaced by *Poa* spp and *Austrodanthonia* spp and numerous herbs such as *Acaena novae-zelandiae, Ranunculus sessiliflorus* and the fern *Adiantum aethiopicum.* In some places, *Acacia pycnantha* may form a definite stratum.

e) Open-forest and woodland of *E. leucoxylon*

This vegetation occurs on the gentle, lower slopes of generally southerly aspects although it may occur from north-east to south-west aspects. *E. melliodora* may be an occasional associate. Soils are deeper and may be gradational or duplex. The understorey is generally grassy, consisting of *Chionochloa pallida, Poa sieberiana, Austrodanthonia* spp, *Austrostipa pubescens and Themeda triandra, although* small shrubs such as *Lissanthe strigosa, Bossiaea prostrata, Acrotriche serrulata* and *Pultenaea pedunculata* are often present.

2) Creek flats of alluvium and colluvium

On these relatively moist sites vegetation is dominated by forest strips of *E. viminalis, E. ovata* and *E. radiata*. In drier sites to the south *E. yarraensis* is present. The understorey is generally *Poa labillardieri* and *Microlaena stipoides*, with patches of dense bracken (*Pteridium esculentum*) and numerous herbs (*Senecio linearifolius, Mentha laxiflora, Epilobium billardierianum*) and *Adiantum aethiopicum.* Along some of the larger stream courses, small patches of shrubs, 2–4 m tall, occur which consist of wet sclerophyllous elements such as *Pomaderris aspera, Prostanthera lasianthos, Gynatrix pulchella* and *Coprosma quadrifida,* together with *Pomaderris ferruginea* and *Leptospermum pubescens.* On moister creek banks they may be associated with ferns such as *Blechnum nudum, Gleichenia dicarpa* and *Asplenium flabellifolium.*

Vegetation on basalt

On the basalt flows to the west of Steiglitz, the original vegetation was probably an *E. ovata* grassy woodland. On basalt in the rainshadow to the east of the Rowsley Scarp, the original vegetation was a woodland of *E. leucoxylon, E. melliodora, E. microcarpa* and *Allocasuarina luehmannii* with *E. camaldulensis* along the stream lines.

VEGETATION-SOIL RELATONSHIPS ON THE TERTIARY CAPPINGS

In the following section, we examine the effects of variation in chemical and physical properties of the

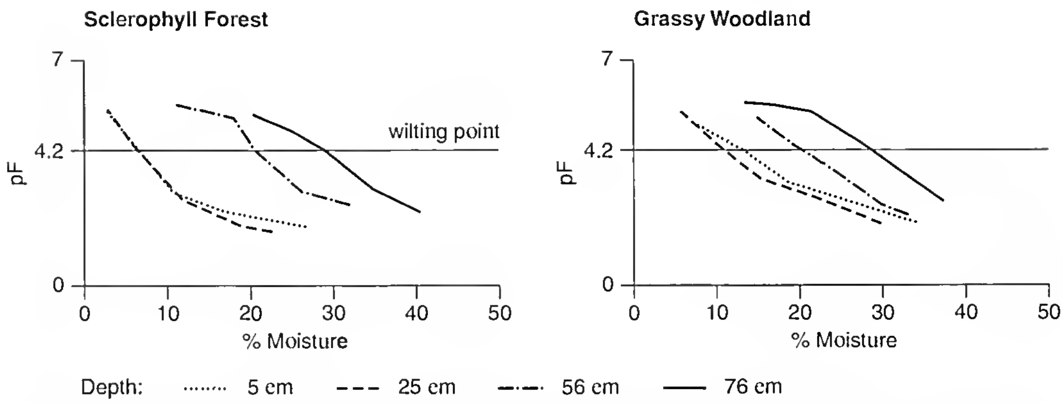

Fig. 17. pF curves for sandy loam (sclerophyll forest) and fine sandy loam (grassy woodland) yellow solodic soils, at depths of 5, 25, 56 and 76 cm.

soil on seedling growth on the dominant eucalypts species as an aid to interpreting the distribution and composition of the major vegetation types on the Tertiary landscapes of the Brisbane Ranges.

1. Physical attributes of the solodic soils of the plateau

These were studied because heavy rains in 1968 resulted in significant temporary waterlogging of grassy woodland soils when the A2 horizon was saturated above a perched water table on the B horizon. In contrast, waterlogging of the sclerophyll forest soils to the east did not occur at this time. Particle size analysis using the hydrometer method (Piper 1942) indicated that the grassy woodland top soils were higher in fine sand and silt than the sclerophyll woodland soils although clay content increased more gradually with depth (Table 4). The pF curves for these soils indicated that the upper 25 cm of the profile in grassy woodland soils had higher moisture contents at wilting point (pF 4.2) than sclerophyll forest soils (Figure 17). The tendency for grassy woodland soils to disaggregate on wetting is strong, especially in the A2 horizon. That horizon may be semi-fluid in very wet years and set hard in dry years.

2. Nutrient status of solodic soils

The nutrient status of the soils is generally low in terms of agricultural potential but those of the grassy woodlands in the west were cleared soon after colonization and utilized pastorally. The levels of 'available' P in the top soils of grassy woodlands are higher than those of the sclerophyll open-forests. Total N and some of the exchangeable cations, such as K and Mg, are about twice as high (Table 5).

Bioassay pot experiments were established in the glasshouse at Melbourne University using top soil (0–15 cm; that had been passed through a 1 cm sieve) from both sclerophyll forest and grassy woodland. Seed of *E. macrorhyncha* and *E. obliqua* from sclerophyll forest and *E. ovata* and *E. viminalis* from grassy woodland in the area were sown in pots 12 cm diameter and 10 cm deep. The total dry weight of seedlings was obtained on harvesting after five months. Growth of eucalypt seedlings — as measured by both dry weight and height — was considerably higher in free-drained fine sandy solodic soils of the grassy woodland than in the coarse sandy solodic soils of the sclerophyll woodlands (Table 6). However, root: shoot ratios were lower in seedlings grown on the fine sandy soils from the grassy woodlands than on soils from the sclerophyll forest.

3. Waterlogging experiments using eucalypt seedlings

A pot experiment was established in the glasshouse at Melbourne University in order to subject seedlings of two contrasted pairs of eucalypt species to different degrees of waterlogging — viz. *E. macrorhyncha* and *E. obliqua* from sclerophyll open-forest and *E. ovata* and *E. viminalis* from grassy woodland. Seed was collected from the soil sites studied. Sieved top soil (0–15 cm) was placed in pots 12 cm diameter and 10 cm deep which were either free drained or

Vegetation	Soil Type	Depth	cm	pH 1:5	Total N (%)	P (0.1N H_2SO_4)	Cations (ppm)				
							K	Ca	Mg	Fe	Mn
Sclerophyll Forest/ Woodland	Sandy	A_1	0–8	5.3	0.045	0.40	50	100	172	1050	19
	loam	A_2	20–25	5.5	0.024	0.15	30	45	77	570	3
	Solodic	B	102–110	5.5	0.028	0.20	49	45	400	280	3
Grassy Woodland	Fine	A_1	0–8	5.1	0.066	0.55	100	140	340	955	45
	sandy loam	A_2	20–25	5.5	0.052	0.40	60	50	240	790	8
	Solodic	B	102–110	5.6	0.052	0.15	66	50	206	430	5

Table 4. Nutrient analyses of soil profiles on Tertiary capping.

Vegetation	Soil Type	Depth (cm)		Texture	Coarse Sand	Fine Sand	Silt	Clay	Fine Sand: Coarse Sand	Organic matter (%)
Sclerophyll Forest	Sandy loam Solodic	A_1	0–10	Sandy Loam	39	42	6	13	1.09	5.0
		A_2	10–20	Sandy Loam	39	38	9	12	1.23	1.9
		B_1	25–36	Clay	14	34	4	48	2.44	2.7
		B_2	46–61	Clay	6	12	1	81	2.00	0.9
		B_3	61–76	Clay	12	15	1	72	1.25	–
Grassy Woodland	Fine sandy loam Solodic	A_1	0–10	Loam	10	61	14	15	6.25	6.0
		A_2	10–20	Loam	11	56	15	18	5.26	5.5
		B_1	25–36	Loam	19	46	9	26	2.44	2.1
		B_2	46–61	Clay	6	22	10	62	3.70	2.7
		B_3	61–76	Clay	4	23	8	65	5.88	–

Table 5. Particle size analyses (% oven dry weight) of soil profiles on Tertiary capping.

placed in troughs where the experimental watertable was maintained at or 5 cm below the soil surface. Both survival and morphological changes of seedlings were noted over 5 months after which plants were harvested and total dry weight, root:shoot ratios and shoot height recorded.

Growth of all species was poorest under complete waterlogging (Table 6) but was particularly low for *E. macrorhyncha*, the roots of which turned black. Mortality of seedlings of this species was relatively high. Root:shoot ratios of all species tended to be lower in grassy woodland soils than sclerophyll forest soils. *E. ovata* showed higher growth and survival than *E. macrorhyncha*, and roots of *E. ovata* developed the reddish coloration of ferric oxide. In some instances roots grew out of the soil for a short distance and developed aerenchymatous tissue in the exposed cortex. Such tissue also occurred in the stem at soil level. The seedlings of this species were clearly better able to cope with the unfavourable anoxic conditions than were seedlings of *E. macrorhyncha* which, in the field, is confined to well-drained soils.

DYNAMICS OF VEGETATION ON THE TERTIARY CAPPING AREAS

Disturbance in the sclerophyll and grassy open-forests-woodlands has occurred at different scales, rates and intervals. This has been a consequence of bushfires, root disease, drought, fire-wood harvesting and, to various degrees, of herbivory by feral, native and domestic animals.

Sclerophyll open-forest

A large area of this community was burnt in the severe fire of September 1967. This resulted in rapid vegetative regrowth of resistant species and abundant flowering of the understorey in the following wet year. In particular, *Xanthorrhoea australis* flowered prolifically and hard-seeded species, such as *Acacia myrtifolia*, germinated abundantly from soil-stored seed. Over the following decades shrubs of this species degenerated and all but disappeared. The root disease, *Phytophthora cinnamomi*, spread in the early 1960s, probably following the spreading of infected gravel on the main roads before they were sealed with bitumen. The spread of the disease was rapid and relentless and the reduction of many sclerophyll species has been fully documented by Weste et al. (1973). The decline and death of susceptible individuals of *E. obliqua* and *E. macrorhyncha* were a feature of these forests for some decades, but the death of *Xanthorrhoea australis* and *Isopogon ceratophyllus* was spectacular. However, continued work over 30 years revealed that the distribution of the disease had become patchy so that in some places *Xanthorrhoea australis* showed signs of regeneration — the origin of the seed supply is unknown since flowering and seeding of this species in the absence of fire is rare. In some places resistant species such as *Lepidosperma semiteres* and *Hakea decurrens* proliferated to form dense strata. The dominance of *H. decurrens*, however, was severely curtailed in the 1990s by stem cankers caused by a species of zylorectid moth (Weste and Ashton 1994).. The relative species composition of this community type has probably been changed permanently as a result of this root fungus infestation, although further perturbations are likely to occur as a result of fires and fluctuating herbivore populations. Excluding herbivores from the understorey produced few differences except for increases in the leguminous shrubs *Platylobium obtusangulum* and *Dillwynia glaberrima*.

Grassy woodlands

Fire has been rare in these communities over the last 5–6 decades but soil conditions have imposed severe limitations to growth of regeneration. The eucalypt species present regenerate as suppressed lignotuberous regrowth in large gaps between the overstorey trees. The scrub patches of *Allocasuarina littoralis* vary in density and cover and degenerating stands now show regeneration from seedlings and root suckers (Figure 18).

In the area 1 km north of Durdidwarrah Reservoir in 1967, occasional *E. obliqua* trees were observed on almost imperceptible rises in *E. ovata*, *E. viminals* and *E. pauciflora* woodland. A striking feature at this time was the establishment of *E. obliqua* seedlings and young trees in *E. ovata*- *E. viminalis* woodland several metres from the isolated parent trees of *E. obliqua* (Figure 19). The re-investigation of this area in 2003 revealed that several patches of young *E. obliqua* forest 10–30 m in diameter had included old or dead trees of *E. ovata*. *Eucalyptus obliqua* seedlings, moreover, were continuing to invade *E. ovata* woodland up to 15–20 m from the parent stand (Figure 20).

		Freely Drained		Half Waterlogged		Fully Waterlogged	
Vegetation Type	**Species**	**Soil Type**		**Soil Type**		**Soil Type**	
		Sandy loam Solodic	**Fine sandy loam Solodic**	**Sandy loam Solodic**	**Fine sandy loam Solodic**	**Sandy loam Solodic**	**Fine sandy loam Solodic**
Dry Weight (g)							
Sclerophyll Forest Species	*E. macrorhyncha*	2.21 (1.46)	22.76 (3.31)	0.87 (0.98)	3.41 (1.55)	0.23 (0.55)	0.82 (0.82)
	E. obliqua	4.93 (1.51)	22.70 (2.83)	1.30 (0.85)	4.47 (1.83)	0.36 (0.54)	1.22 (0.84)
Grassy Woodland Species	*E. viminalis*	5.51 (1.33)	17.46 (2.95)	2.03 (1.00)	4.73 (1.38)	0.39 (0.75)	2.15 (1.13)
	E. ovata	5.16 (0.30)	23.30 (1.88)	2.75 (1.20)	9.00 (1.58)	0.31 (0.66)	4.04 (1.42)
Height (cm)							
Sclerophyll Forest Species	*E. macrorhyncha*	15.8 (2.84)	50.2 (2.16)	8.0 (2.63)	14.6 (2.24)	3.4 (1.39)	12.3 (1.35)
	E. obliqua	24.7 (3.15)	52.5 (2.38)	7.0 (2.01)	23.4 (3.16)	6.0 (1.86)	13.2 (3.62)
Grassy Woodland Species	*E. viminalis*	33.8 (3.28)	59.0 (3.10	14.0 (2.48)	28.7 (2.42)	9.1 (2.37)	20.3 (3.09)
	E. ovata	30.4 (3.27)	58.2 (2.40)	18.3 (2.91)	36.8 (4.02)	8.8 (1.85)	29.0 (2.61)
Root:Shoot Ratio							
Sclerophyll Forest	*E. macrorhyncha*	0.76	0.42	0.77	0.31	1.39	0.72
	E. obliqua	0.60	0.33	0.60	0.44	0.62	0.91
Grassy Woodland	*E. viminalis*	0.83	0.39	1.29	0.71	1.52	0.62
	E. ovata	1.11	0.61	1.01	0.93	1.75	0.81

Table 6. Growth of *Eucalyptus* seedlings in freely-drained and aerated soil, half waterlogged soil and fully waterlogged soil from Sclerophyll Forest (Sandy loam solodic) and Grassy Woodland (Fine sandy loam solodic). Figures are mean (+ SD in parentheses), based on 5 months growth, and 5–6 replications per treatment.

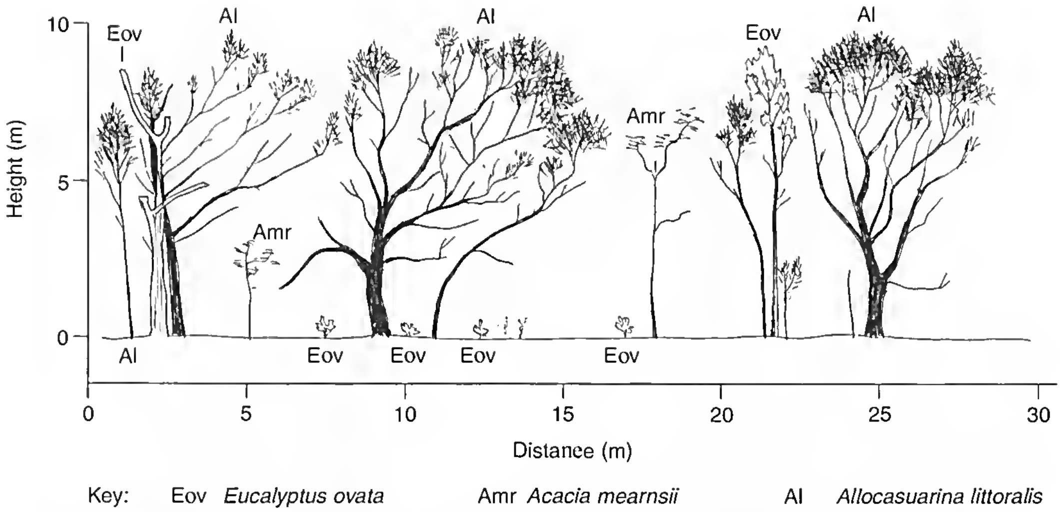

Fig. 18. Vegetation profile of *Allocasuarina littoralis* scrub degeneration and regeneration in grassy woodlands.

In some dense patches of *Allocasuarina littoralis-Banksia marginata* in 1968, relatively young trees of *E. ovata* trees had died, but in mature degenerating patches in 2004, regeneration by seedlings of both the scrub species and *E. ovata* was occurring. No *Phytophthora cinnamomi* infection has been found in these areas and all the species tested have proved to be resistant (Weste et al. 1973). The long term rainfall records for Durdidwarrah indicate that in the decade before the observation of *E. obliqua* invasion, rainfall was well above-average (Figure 6).

PLANT GEOGRAPHIC RELATIONSHIPS

The rain shadow of the Brisbane Ranges in the lee of the Western Highlands supports a rich flora of over 430 vascular species with floristic links to both east

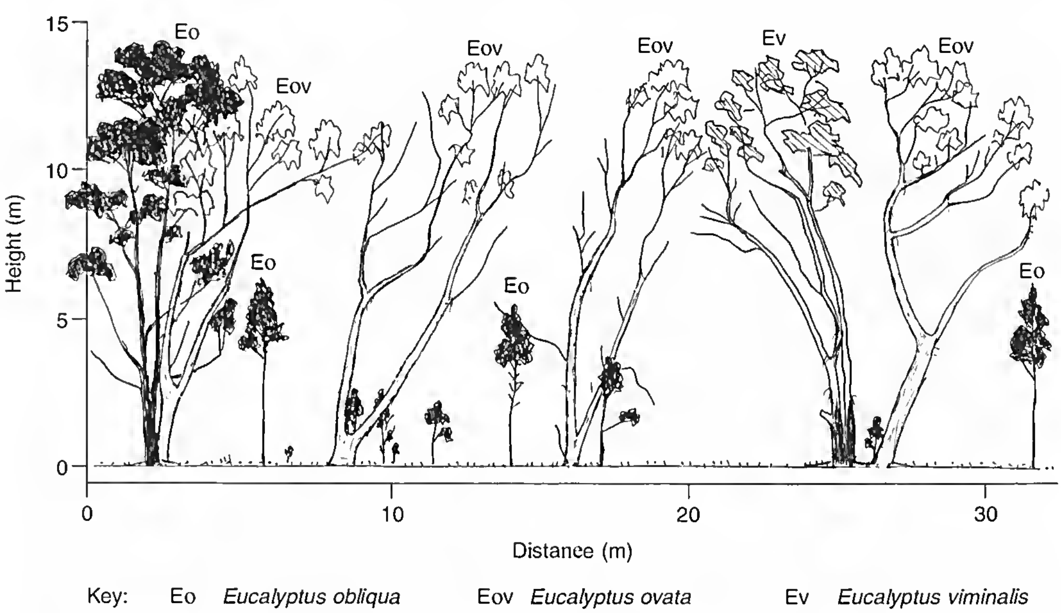

Fig. 19. Vegetation profile through the early invasion of *Eucalyptus ovata* woodland by *E. obliqua* in 1967.

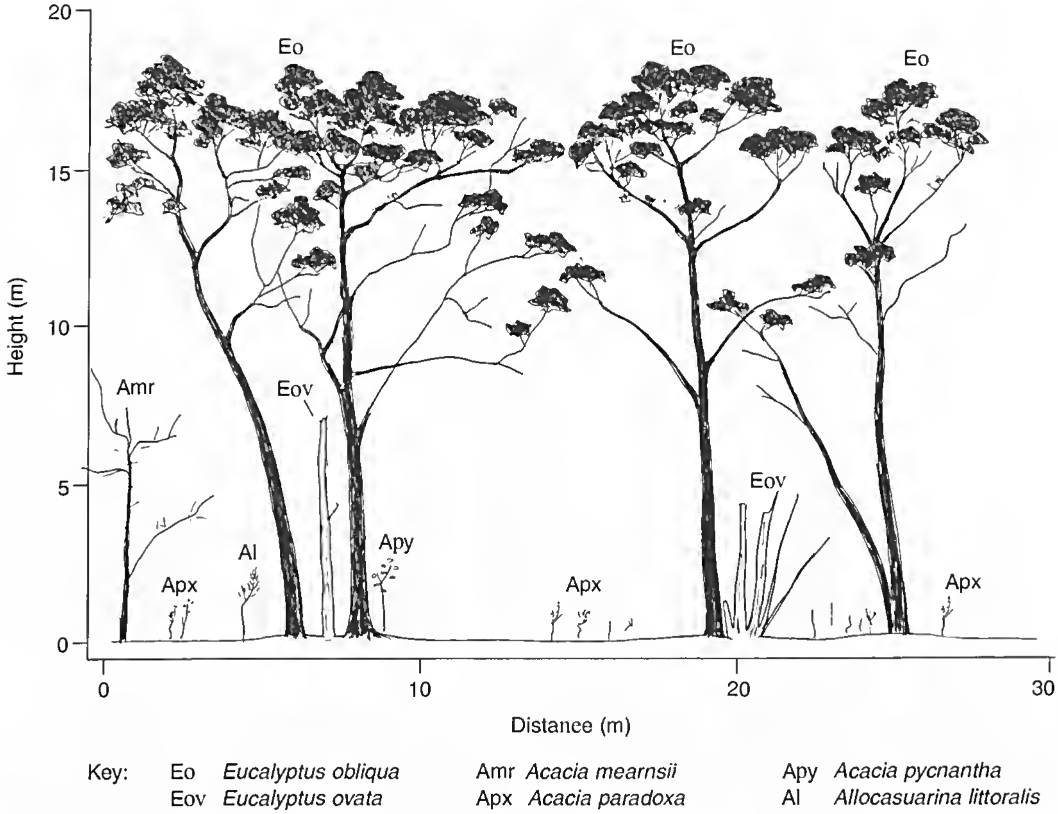

Fig. 20. Vegetation profile through a patch of young *Eucalyptus obliqua* forest in the later stages of the invasion of *E. ovata* grassy woodland.

and west Victoria (Willis 1962). The general area from Melton-Bacchus Marsh north-west to Lethbridge also harbours species characteristic of dry country to the north such as *Callitris glaucophylla, C. gracilis, Eremophila deserti, Rhagodia parabolica, Maireana pentagona, Sclerolaena divaricata, Eucalyptus microcarpa* and *Allocasuarina luehmannii.* Species of western Victoria that reach the Brisbane Ranges area include *E. leucoxylon, E. aromaphloia, Leucopogon glacialis* and *Pultenaea graveolens,* whereas those characteristic of eastern Victoria include *Grevillea chrysophaea, Pomaderris ferruginea, Pomax umbellata* and *Phebalium lamprophyllum.* The only species endemic to the Brisbane Ranges is *Grevillea steiglitziana.*

It is possible that vegetation from drier areas north of the Great Dividing Range extended through the Kilmore Gap and along the western side of the Port Phillip Sunkland. Such vegetation may have been stranded in a rain shadow when climatic conditions later ameliorated. It seems likely that dry conditions prevailed during the early Holocene, as indicated by the re-mobilization of sand dunes in southern Victoria and Tasmania (Bowler 1966). It is likely that both past and present climatic variation, as well as dispersal barriers, have been involved to various extents in the present-day distributions of species. The Brisbane Ranges, with its varied array of edaphic and topographic conditions, therefore occupies an important position in the east-west floristic gradient of Victoria.

DISCUSSION AND CONCLUSIONS

Although modified by past climatic history, the vegetation and soils in the Brisbane Ranges are controlled largely by geology and physiography. Soils developed on lateritized Tertiary sandy clays of the plateau are leached, solodic and duplex but vary in texture and structure from east to west in accordance with the grain-size spectrum of the parent material. Coarser sandy loams in the east are associated with sclerophyll forest and finer hard-setting loams in the

west are associated with grassy woodlands. On Ordovician bedrock, an aspect/slope continuum (Ashton 1976) of sclerophyll and grassy sclerophyll forests and woodlands are associated with skeletal soils or with deeper solodic types akin to those of the western areas of the Tertiary capping. The transition from sclerophyll shrub to predominantly grassy understoreys on the Tertiary capping plateau is correlated with a moderate increase in nutrient status, particularly that of phosphorus availability. This parallels other studies elsewhere in south-eastern Australia, such as in the Mt Lofty Ranges of South Australia (Specht and Perry 1948), in the Sydney district (Beadle 1962; Watson 2005), the New England Tableland of NSW (Clarke 2003) and in other areas of the mainland (Gill 1994), where the occurrence of grassy woodlands has been shown to occur on finer textured soils of relatively high nutrient status. In Tasmania, although grassiness in lowlands is often associated with richer soils and sclerophyll shrub understoreys with poor soils (Duncan 1999), repetitive firing may result in grassy understoreys on siliceous soils whilst richer, fractured rocky substrates may favour shrubby understoreys (Kirkpatrick 1999). Nutrient increases, however, are often associated with greater colloid content which may also affect soil moisture relations and result in the so-called 'inverse texture effect' (Walter 1951, Rowan and Downes 1963, Parsons 1994). This may result in finer-textured soils having lower moisture availability and storage, particularly in drier climates. This feature in the Brisbane Ranges is indicated by an increase in silt and clay in the grassy woodland sites where poor structure is associated with a strong tendency to waterlogging in wet seasons and to be drought prone in dry years. Species on such sites may need to be tolerant to both anoxic soil conditions and drought. *Eucalyptus ovata* seedlings have been shown to be more tolerant of waterlogging than *E. viminalis* (Ladiges and Kelso 1977) and, in the present study, both of these species were more tolerant than the eucalypts found in better-drained sclerophyll open-forest, particularly *E. macrorhyncha*.

Most of the eucalypt-dominated vegetation is multi-aged with sporadic, generally suppressed regeneration. Disturbance in the past has been due to fire, biotic factors and climate variations. Fire has been a recurrent disturbance in most sclerophyll forests but regeneration of the original species composition — following the initial floristic composition model of secondary succession (Egler 1954; Purdie and Slatyer 1976) — is the norm, albeit with some changes in species abundance (Gill 1994).

A much more pernicious disturbance has occurred in the sclerophyll forests on the Brisbane Ranges due to *Phytophthora cinnamomi*. Weste (1997) and Weste and Taylor (1971) have documented changes in species composition in these communities which in some places have been shown to be permanent, while others have shown partial recovery. The destruction of *Xanthorrhoea australis* over large areas has changed the physiognomy of the community profoundly over the last 40 years.

The grassy woodlands have remained unburnt for many decades and the large patches of *Allocasuarina littoralis* scrub present may be a consequence of the absence of fire, similar to that found in woodlands at Ocean Grove (Withers and Ashton 1977; Lunt 1998) where eucalypt associates have died in the presence of drought-resistant competitors. At present, many scrub areas are either mature or dying and show evidence of regeneration of both scrub species and eucalypts, suggesting that this mosaic pattern may be self-sustaining.

In some areas north of the upper Stony Creek Reservoir, *Eucalyptus obliqua* has invaded *E. ovata-E. viminalis-E. pauciflora* woodland over a period of 35 years, forming patches of forest. It is possible that the decades of the 1950s and 1970s were sufficiently wet to enable *E. obliqua* seedlings from isolated pioneer trees to establish in adjacent woodland. It is not known whether this succession will continue.

Past changes in climate are suggested by the presence of sand-sandy loam lunettes in the lee of swamps in the western plateau areas of the Tertiary capping and in sand deposits infilling depressions to the east. Prolonged recent droughts have enabled the sandy floors of dried out swamps to be blown onto adjacent lunettes thus indicating an ongoing process dependent on climatic conditions. The broad perspective of the species' distributions in the Brisbane Ranges-Melton rain-shadow area may suggest an extension of dry climate vegetation from the north of the Great Dividing Range at a time of Quaternary aridity. The current composition of the vegetation reflects such changes in climate, and the Brisbane Ranges therefore occupy an important plant geographic link between eastern and western Victoria.

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OF

THE ROYAL SOCIETY OF VICTORIA

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TRANSACTIONS

OF

THE ROYAL SOCIETY OF VICTORIA

Volume 118

NUMBER 1

A RECEPTION TO ANNOUNCE
RSV — INTREPID

THE SOCIETY'S TWO ANTARCTIC EXPEDITIONS PLANNED FOR YOUTH DURING THE FOURTH INTERNATIONAL POLAR YEAR

Wednesday 15th March 2006
In the Society's Hall
in the presence of
HRH Prince Philip, The Duke of Edinburgh

WELCOMING ADDRESS

His Royal Highness, Prince Philip, Duke of Edinburgh; assembled Antarctic Expeditioners, my fellow Councillors and Invited Guests.

It is a great pleasure to welcome you to The Royal Society of Victoria for this historic event. I cannot believe my good fortune — that my term of presidency should have coincided with this celebration. It is just 50 years since His Royal Highness was last here. He came for the 1956 Olympic Games, and presented medals to the polar expeditioners — our Antarctic explorers. Of the 23 Polar Medallists, we have I believe 15 of them here today. I find it interesting that the procedures used to select these men for Antarctic exploration obviously chose men who have sustained a long life. Speaking with them, they have also had most interesting lives.

Today, we have an opportunity to excite the Youth of Australia with an event that could equal that experienced by our Polar Explorers. Our next speaker, Captain Bill McAuley, Councillor and Honorary Treasurer of The Royal Society of Victoria will tell you about our plans for INTREPID.

As detailed in your booklet, INTREPID is a voyage of discovery for young people to Antarctica — in fact two voyages of discovery, to be held during the summers of the International Polar Years 2007 and 2008, and it is the Society's contribution to the celebrations for this the Fourth International Polar Year.

Sir, I call upon Captain Bill McAuley to inform you further about INTREPID.

B. G. Livett
President

INTRODUCTION TO RSV — INTREPID

A very warm welcome to Your Royal Highness,
Senator Ian Campbell, our Federal Minister for The Environment and Heritage,
Dr. Martyn Joshi, Consul General of India,
Dr. Carlos De Lemos, Consul General of Portugal, and Secretary to The Consular Corps in Victoria,
Mr. Jan Ravnholt, Consul General of Denmark,
Mr. David Seddon, Deputy-Consul General of The United Kingdom,
The Very Reverend Michael Protopopov of The Russian Orthodox Church,
Dr. Ian Allison, Co-Chairman of The IPY Joint Committee,
Prof. John Long, Head of Science in The Museum of Victoria,
Dr. Tony Press, Director of The Antarctic Division,
Mr. John Wigley, District Governor of Rotary International,
Mr. Mark Williams, Regional Director of The Bureau of Meteorology in Victoria,

and last, but not least, my old professor, Dr. Larry Harrington, Geologist, Everest Mountaineer, Antarctic Explorer and Polar Medallist,
Other Distinguished Guests.

We are now at D-Day Minus 350. On March 1st next year we shall launch this society's contribution to The 4th International Polar Year.

RSV-INTREPID will see our 2 expeditions mounted aboard a class-one icebreaker working in The Antarctic over 40 days each summer, to engage roughly 200 young people in investigative science, both ashore and afloat.

Their routine will be demanding. It will be based on the ship's 24-hour watch-keeping system. Those of you who have served in The Grey Funnel Line will be alive to that regime and its discipline.

The tasks set by our colleagues from The Antarctic Division, The Bureau of Meteorology, CSIRO and the Universities will be challenging.

The young expeditioners will not be idle. They will be our best, selected on merit from their second last year at school, a year before they matriculate. They will be mentored by enthusiastic, young, post-graduate men and women having the carriage of some very exciting investigative scientific programs.

INTREPID is unique. It will be the first time an enterprise of this nature has been undertaken. No other country, let alone scientific society such as this, has ever been granted the honour of conducting such a thing. With over 1000 Expressions-of-Interest received by The IPY Joint Committee in Cambridge, The Royal Society of Victoria's vision for INTREPID was identified and selected as the only expedition matching The Education, Outreach and Communication objectives laid-down for the IPY. This is a signal honour for me as Leader and for this Society.

Seldom does anyone have such a wonderful opportunity, and the temptation presents to dwell more on one's own effort; but this is a story about others — some present, some past, and the credit really falls on them.

Tribute must be granted to a number of individuals, including The Late Mr. Paul Kill, a school-teacher with vision and vigour, who inspired this society to take such a gamble, calculated though it may be.

The Late Professor Neil Archbold (our Past President) and Emeritus Professor Nancy Millis nominated me as a Member-of-Council, and supported my notion to see INTREPID succeed. I would not be standing here today had it not been for their faith in me.

This ambitious undertaking remained a marvellous idea which lay dormant in the absence of any prospect of funding until a Member of The Society raised the spectre and promise of the forthcoming IPY. The spark of INTREPID was re-ignited and caused detailed planning to resume to meet the deadline imposed by our companions in Cambridge. We had about 10 days to submit what was, and remains, a very bold plan. We could, Your Royal Highness, ladies and gentlemen, no longer rely on smoke and mirrors to do the job.

This Society is leading by example. I express the hope that we'll be supported, and that as Leaders in your own right, you each use your influence and get behind us. Great good can come from this endeavour, but it will rely on your help.

Achieving your aim brings success. My aim is to see that the success this society will enjoy is shared for the benefit of Youth — our Leaders of The Future.

This is a precious opportunity for The Youth of today who will become The Leaders of tomorrow.

The Royal Society of Victoria is back in The Antarctic exploration business.

It does not intend to squander the possibilities offered by returning to the ice.

Procul omen abesto! (Far be that fate from us)

W.J.W. McAuley
Leader
RSV — INTREPID

A RETROSPECTIVE

Mr President, Your Royal Highness, Guests, Ladies and Gentlemen

On 3rd December 1956 in this Hall, when Your Royal Highness opened The Royal Society's Symposium on Antarctica, none of those present could have envisaged our being present here today, 50 years later.

Nor could we have foreseen the remarkable achievements of the IGY in Antarctica which was about to begin, or the political developments regarding Antarctica that were to follow the IGY.

I refer to the creation of the Antarctic Treaty, the freezing of national territorial claims in Antarctica and the collaboration in international scientific researches arising from the organisation of SCAR (The Scientific Committee for Antarctic Research).

Today's meeting is a kind of mirror image of the 1956 event, for next year another International Polar

Year is to commence. What the fallout of that would be one would not dare to predict, but research in the field of global warming will certainly be a feature.

The Royal Society of Victoria is proud to be able to play a small part in this world program.

P. G. Law

CLOSING REMARKS

Your Royal Highness, Polar medallists, distinguished guests, ladies and gentlemen,

This is a significant day in the 150-year history of The Royal Society of Victoria. We celebrate the achievements of the past and plan for the future.

We can look back with pride on the role of the Society, and it members, in the establishment of the scientific and cultural organisations of Melbourne. They include the universities, the museums, the State Library, the Botanic gardens and the development of public utilities and services to name but a few.

Today although the exterior of our historic, heritage classified, building is sadly in need of refurbishment, within our heart beats as strongly as ever.

- We are the only Royal Society in Australia which has retained its building.
- We have more members than at any time in our history
- We continue our task of supporting scientific endeavour and providing a forum for scientific debate and a meeting place which transcends the boundaries of universities and other institutions

Most importantly, we are committed to promoting science and to encouraging students to pursue science as a career and to recognise the importance of scientific enquiry to the well being of the wider society.

For 120 years Society has played an active role in the promotion of Antarctic exploration. The decades following the formation of the Antarctic Exploration Committee in 1886 saw the expeditions of Scott, Shackleton, Amundsen and Mawson, the accounts of which are part of our heritage of bravery and endurance and also bear testimony to the power of scientific curiosity.

Australia and Australians played a large part in this and in the post-war period Australia's role increased substantially. Thus it was that 50 years ago, your Royal Highness, in this hall, presented Polar medals a group of expeditioners. Many of those same medallists, and other Polar medallists, are with us today.

Today as we honour past expeditioners we look forward to providing a new generation with the opportunity to experience the excitement of a career in science.

The Intrepid project planned for the International Polar Years is intended to provide to students an opportunity to experience some of the excitement of Antarctica which inspired so many scientists and members of earlier expeditions, including those present today.

P. G. Thorne
Vice-President

A ROYAL GREETING

My first association with The Royal Society of Victoria was made possible by my presence in Melbourne for the opening of the Olympic Games in 1956. It gave me great pleasure to be able to present Polar Medals to a number of people who had taken part in the Antarctic program of the International Geophysical Year. My second visit, fifty years later, coincided with the opening, by the Queen, of the Commonwealth Games in 2006. On this occasion I was delighted to meet again some of the Polar Medallists of fifty years before.

I am also very pleased to have this opportunity to congratulate The Society on its active work in developing a better appreciation of South Polar regions through its initiative to send two expeditions to Antarctica during the 4th International Polar Year. I have no doubt that the members of those expeditions will have the experience of their lives, and I wish them great success in all their research projects.

H.R.H. Prince Philip,
The Duke of Edinburgh

OFFICIAL DIGNITARIES IN ATTENDANCE

His Royal Highness The Duke of Edinburgh, KG, KT, OM, GBE, AC, QSO

OFFICIAL PARTY

H.R.H. The Duke of Edinburgh

(L-R) H.R.H. The Duke of Edinburgh with veteran Polar Medallists Dr. Phillip Law, Sqn. Ldr. Douglas Leckie R.A.A.F and William Storer Esq., in The Royal Society of Victoria's hall, 15 March 2006, at the reception to announce RSV — INTREPID (The Society's 2 Antarctic Expeditions planned for Youth during The 4th International Polar Year).

The President of The Royal Society of Victoria
The Vice-President of The Royal Society of Victoria
The Leader of RSV — INTREPID
The Executive Officer of The Royal Society of Victoria

POLAR MEDALLISTS

Assoc. Prof. Grahame Murray Budd
Prof. William Francis Budd
Flt. Lt. Peter Hugh Clemence RAAF
Frederick Winton Elliott 1956
Dr. Hilary J. Harrington
Dr. Alf Howard
Frits Adriaan van Hulssen 1956
Leon Neville Eugene Jennings-Fox 1956
Sydney Lorrimar Kirkby
Dr. Phillip G. Law
Sqn. Ldr. Douglas Walter Leckie RAAF
Lt. Col. Richard Milne Lightfoot RAE
Prof. John Potter Masterton
Richard George McNair 1956
Wilfred Hugh Oldham 1956
David Damien Parer
Dr. Neville Ronsley Parsons 1956
Neil Edwin Roberts
Maj. Gen. Neville Robert Smethurst
William Joseph Storer 1956
Dr. Robert Olveston Summers 1956
John Livingstone Ward 1956
Prof. Gunter Ernst Weller

COUNCIL OF THE ROYAL SOCIETY OF VICTORIA

STRANGE OMISSIONS FROM DESCRIPTIONS OF THE MOSS *DAWSONIA SUPERBA*

Dennis J. Carr, 17 Collings Street, Pearce, ACT, 2607.

INTRODUCTION

The book, "The mosses of Southern Australia" by George Scott and Ilma Stone, published in 1976, is a handsome volume, sumptuously illustrated by the drawings of the internationally famous botanical artist, Celia Rosser. These drawings are certainly the finest ever made or published of mosses. By citing her as a junior author on the title page the senior authors absolved themselves from any expression of gratitude for her great contribution which considerably enhances the attractiveness of the volume.

It begins with a preface and keys to the genera and species followed by descriptions of each one; these descriptions include not only the relevant taxonomy and morphology, habitat preferences, and geographical distribution, but also the chromosome number (where known). The volume concludes with a glossary of terms, a reference list and a splendid index.

One of the references listed is that of K. Goebel, a contribution filling the whole of volume 96 of the journal *Flora* (of which Goebel was the editor) for 1906. This is a report (he refers to it as a *kleine Beitrage* — with 202 printed pages!) of the results of his year-long stay in Australia and New Zealand during 1898–99 to observe and collect materials of morphologically interesting plants, mainly mosses and liverworts. That visit, well reported in New Zealand by the botanist L. Cockayne, went unnoticed in Australia until 1981 when my wife and I published a chapter entitled "Karl Goebel in Australia and New Zealand" in our book, "People and Plants in Australia".

The first 45 pages of Goebel's report deal with the giant moss *Dawsonia superba* which he encountered at the Black Spur in the Warburton Range in Victoria where he stayed at a chalet called The Hermitage with its proprietor G.W. Lindt. (I am indebted to Professor Martin Canny RSBS, ANU for a copy of these pages).

Scott and Stone's description of *D.superba* lacks several important facts which could have been gleaned from Goebel's report. The "Handbook of the New Zealand Mosses" by Sainsbury published in 1955, also has similar omissions.

OBSERVATIONS.

After describing the giant (up to 50cm long) leafy aerial shoots of the moss, Goebel states: "in addition there is a strongly-developed, unbranched rhizome, which can reach a length of 15 cm or more" and is buried to a depth of about 6 cm. The rhizome is three-sided (Fig 3) and has scale leaves, each of which may develop a red tip. The rhizome is also covered with a felt of rhizoids which are unusually richly branched. This important fact escaped mention by Scott and Stone, who, despite citing the Goebel reference, appear not to have read it.

Nor is the existence of the *Dawsonia* rhizome mentioned in the more workman-like paper-bound "Handbook of the New Zealand Mosses" by Sainsbury published in 1955. This is despite the more widely known and well published account of Goebel's visit to New Zealand, where he would also have encountered *D. superba*. The two *Dawsonia* species, *D. superba* and the smaller *D. longiseta* are not the only mosses with a rhizome. The fern gully moss *Cyathophorum bulbosum* has a rhizome (not a bulb) and that is mentioned and illustrated in Scott and Stone but they do not mention the rhizome of a species of *Hypopterygium*, another fern gully inhabitant, and a near relative of *Cyathophorum*. Sainsbury merely distinguishes in both genera between what he terms 'primary' and 'secondary' stems. Other authors e.g.Schofield and Hebant, refer to the rhizomes as "stolons" a term which would be inappropriate at least for *Dawsonia* since its rhizomes are fully subterranean.

Another observation of Goebel's is that of the leaf traces (Fig. 1) in both stem and rhizome. These are "true leaf traces" in that their conducting elements join with those of the central cylinder, unlike those of some other mosses. The leaf traces are arranged in three spiralling rows in the lower part of the stem but in the upper parts higher orders of phyllotaxy are achieved (Fig. 2).

Goebel considered the intimate relationship between the rhizome, its rhizoids and the soil as

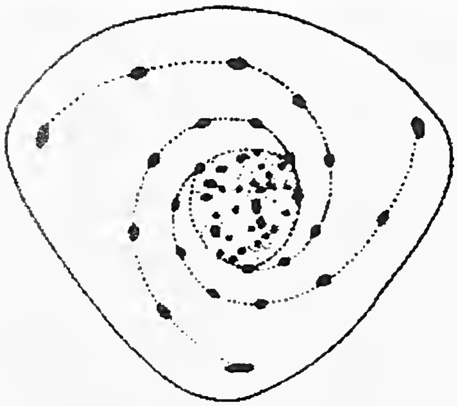

Fig. 1. Section of stem showing spiralling leaf traces.

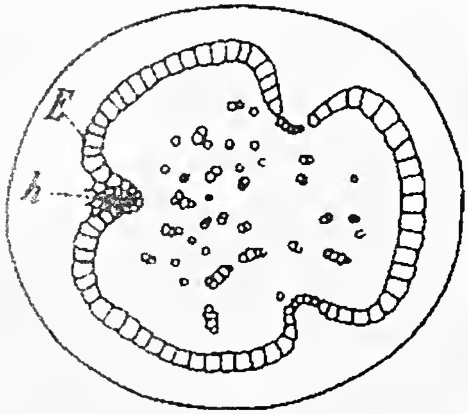

Fig. 3. Section of rhizome. E = endodermis. h = hydroids (water conducting cells).

responsible for the relatively massive growth of the aerial shoots.

Goebel attempted to determine the growth rate of the male shoots. After a period of perhaps more vigorous, vegetative growth, the male shoot produces an antheridiophore which then grows through. It produces an antheridiophore each year. By measuring the distances between the antheridiophores of several shoots he estimated the annual growth as about 2 cm. Thus the larger male shoots had been growing for 20 years or more. This important information is, of course, missing from the accounts in Scott and Stone and from that of Sainsbury.

Much of Goebel's report is concerned with a detailed description of the tissues, mechanical and conductive, of the stem and rhizome. In a magisterial developmental study he demolished an erroneous view put forward by Robert Brown (and subsequently endorsed by many eminent botanists of the 19th century, since it emanated from the "infallible" *Jupiter Botanicus*) that the bristles of the peristome were extensions of the spore sac of the capsule.

Goebel also reported on, and illustrated (Fig. 4), the stomata on the apophysis of the capsule. This character is omitted from the description by Scott and Stone and that of Sainsbury , although they do report the presence of stomata in the related genus *Polytrichum* and their absence in the sister genus *Pogonatum*. Despite the presence of stomata on the capsules of many other species of mosses there is no further mention of them in either book.

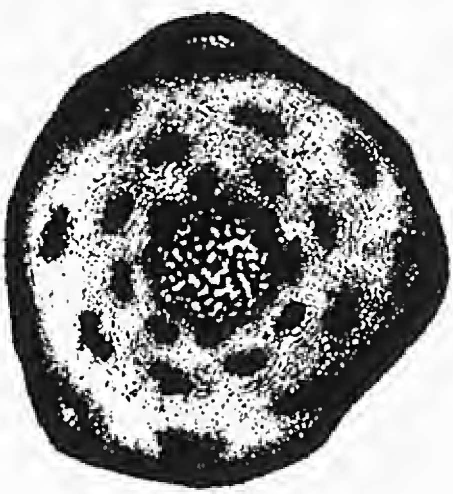

Fig. 2. Section of stem (higher up than Fig. 1) leaf traces with a phyllotactic pattern of (3:8).

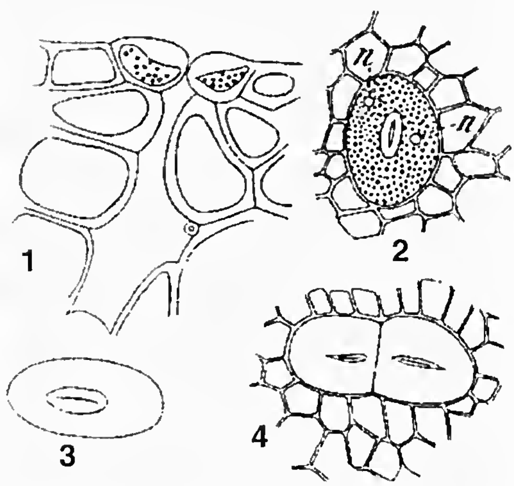

Fig. 4. Stomata on the apophysis. 1, in section. 2–4, in surface view. n=nucleus.

CONCLUSION

This study shows that modern authors ignore the work of past writers even in relatively accessible languages, at their peril. Thus knowledge gained is far too readily lost unless vigilance prevails.

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OBITUARY — D. H. ASHTON
DAVID HUNGERFORD ASHTON, OAM, FFRSV
6TH JULY 1927 — 22ND NOVEMBER 2005

LINDEN GILLBANK

History and Philosophy of Science Department University of Melbourne VIC 3010

In 1995 Dr David Ashton was elected Foundation Fellow of The Royal Society of Victoria (RSV) for his 'outstanding and widely recognised contributions to science in Victoria'. In thanking the RSV for 'the impressive night of the induction of the first fellows' he noted that he had joined in his 'MSc days 1951 or 2'.[1] From the Botany School at the University of Melbourne, David was studying the majestic Mountain Ash, aptly named by Mueller *Eucalyptus regnans*. His supervisor, the Cambridge-trained professor of botany, Dr John Turner, was the RSV president and encouraged postgraduate students to join the RSV. David was an associate member until he was elected a full member in 1961, by which time he was a University lecturer with a PhD degree awarded for his pioneering ecological investigations of Mountain Ash.

In joining the RSV and having his papers published in its *Proceedings*, David Ashton was following a long line of botanists — Dr (later Baron) Ferdinand (von) Mueller in the nineteenth century, and, in the twentieth century, Turner and his predecessor, Dr Alfred Ewart, and their colleague, Dr Reuben Patton. Patton's papers on trees and his series, 'Ecological studies in Victoria', appeared in the RSV's *Proceedings* before he taught David Ashton ecology in 1948.

David's school and university studies shaped his decision to become a botanist. He studied agricultural botany and geology at Melbourne High School, and was one of only three non-returned-servicemen accepted into the agricultural science course at the University of Melbourne in 1946. During our conversations not long before he died, he recalled his first-year botany excursions to Frankston heathlands and Dandenong Ranges forests and his pleasure at being in a group led by the ecologically-enthusiastic Professor Turner. David was so impressed that plants had names and ecological reasons for growing where they did, that he switched from agriculture to science and majored in botany and geology. He also remembered his third-year ecology excursion with Dr Patton to east Gippsland forests in 1948. By then David was also enjoying expeditions with a society established for field investigations, the McCoy Society.

Keen to encourage ecological research in the Botany School, Professor Turner handed David Ashton, newly BSc, an ecological puzzle for his postgraduate research project, thereby seeding, and perhaps sealing, his fate as an ecologist. It was well-known that Mountain Ash regenerated vigorously after fire; but could it regenerate without fire, perhaps in forest gaps? Professor Turner suggested venerable stands of *Eucalyptus regnans* in Melbourne's water catchment on the Great Dividing Range north of the thirsty city — the Big Ash forest in the Wallaby Creek catchment on the Hume Range. In 1949 David began the difficult and arduous task of mapping the vegetation and soils of the Big Ash forest and began an investigation of regeneration in these long-unburnt stands — a tall order indeed for an MSc project. His ecological ideas were significantly shaped by the renowned ecologist of 'pattern and process' fame, Dr Alex Watt, whom Professor Turner invited out from Cambridge in 1950 and whom David considered his 'botanical father'. David's complex and protracted investigations grew into a doctoral project, and, despite weather-, wombat- and leech-induced tribulations, he managed to reveal many details of the Mountain Ash's life-story, including its apparent ability to regenerate in a forest gap.

While a postgraduate student and demonstrator in the Botany School, David thrice joined Professor Turner's annual summer team to help Maisie Fawcett (later Mrs Carr) assess the vegetation in grazed (unfenced) and un-grazed (fenced) areas, which she had established on the Bogong High Plains in the mid-1940s. The labour-intensive Levy point method used to assess the vegetation required the recording of each leaf pierced or touched by long thin vertical wires at many hundreds of points. After arduous day-time bums-up and heads-down Levy point generation of vegetation data, David and others produced

1 Correspondence between Drs Max Lay and David Ashton in June and October 1995, in David Ashton's correspondence file in The Royal Society of Victoria.

Fig. 1. David Ashton pondering on *Poa* and *Stilbocarpa* on Macquarie Island, December 1964 (Malcolm Gill photo).

humorous sketches and cartoons during entertaining evenings in the Rover Scout Hut.

David Ashton organised subsequent vegetation assessments and supervised Dick (R J) Williams' doctoral investigations of grasslands on the Bogong High Plains. In the 1980s, over four decades after their 1939 (post-fire) regeneration, numerous shrubs were senescing above carpets of grass, allowing Dick Williams to confirm the cattlemen-confronting irony that Maisie Carr had reported at the RSV's Victorian High Plains Symposium in 1961 — that grasses eventually replace heathland shrubs.

Both the High Plains and the Wallaby Creek investigations reveal the crucial importance of long-term studies, with decades, not years, being required for the elucidation of adequate ecological explanations. Had David Ashton transferred his ecological attention away from the Big Ash forest in the 1950s, he would not have noticed the subsequent demise of the few saplings that had managed to grow in a forest gap, and would not have been provoked to ask further questions and examine in more detail the biology and ecology of *E. regnans* in order to properly explain the intimate intricacies of its life.

Appointed a senior demonstrator in the Botany School in 1954, David Ashton was awarded a University of Melbourne PhD degree in 1957 for his thesis, 'Studies on the autecology of *Eucalyptus regnans* F.v.M.', and a Nuffield Travelling Scholarship so that he could work with Watt at Cambridge in 1958. In 1959 Dr Ashton had a German Government grant to work at research institutes in Stuttgart and Munich, and a Rockefeller grant to discuss his Mountain Ash research at the Ninth International Botanical Congress at Montreal in August. After visiting North American institutions and forests, he returned to a Melbourne University lectureship in November 1959.

While continuing his Mountain Ash research, Dr Ashton interested generations of Melbourne University students in the ecology of diverse plant communities, and contributed numerous plant specimens to the University herbarium (MELU). From 1960 he taught ecology to science and forestry undergraduates, introducing them to various plant communities during day-excursions and a week-long pre-first-term excursion (with the McCoy Society's marquee providing shelter). The annual extended excursion to often undocumented plant communities at Wilson's Promontory, Lake Mountain, the Snowy River Valley near Suggan Buggan, Mt Cobbler, Bennison High Plains, Errinundra Plateau or the Den of

Fig. 2. David Ashton with postgraduate research student, Pauline Ladiges, and her de-potted *Eucalyptus viminalis* plants in a glasshouse experiment in 1969 (Truda Straede photo).

Nargun (after the Ash Wednesday fires in 1983) allowed undergraduates to undertake detailed ecological field studies, and often prompted postgraduate research projects under Ashton's supervision.

Dr Ashton's ecological interests extended beyond Victoria. He was keenly interested in the vegetation on Macquarie Island, and accompanied most of the December resupply/changeover expeditions to Macquarie Island in the 1960s. In 1968 he gave an invited paper at the Antarctic Biology Symposium (organised by the Scientific Committee on Antarctic Research) at Cambridge, England — 'Productivity Studies on Macquarie Island Vegetation' co-authored with his postgraduate research student, John F Jenkin.

Senior lecturer from 1964 to 1976, Dr Ashton helped his former MSc research student, Judy Frankenberg, with plant community information for her conservation survey. Frankenberg's *Nature Conservation in Victoria* (VNPA 1971), Victoria's first conservation survey, revealed the sometimes urgent need for the conservation of many of the plant communities which Dr Ashton had the ecological foresight to have his postgraduate research students investigate.

His students' diverse doctoral research projects include Malcolm Gill's study of eucalypt forests near Wallaby Creek, John Jenkin's study of Macquarie Island plant communities, and Truda Howard's study of Myrtle Beech, *Nothofagus cunninghamii*, in the 1960s; Pauline Ladiges' study of variation in Manna Gum, *Eucalyptus viminalis*, in relation to mineral nutrition and drought resistance, Jenny Withers' study of eucalypt woodland remnants at Ocean Grove, Rod Seppelt's study of the moss flora of Macquarie Island, Philip Smith's study of variation in the messmate (*Eucalyptus obliqua*) complex at Wilson's Promontory and Rick Willis' study of allelopathy in mountain ash forests in the 1970s; and, in the 1980s, Kevin Clayton-Greene's study of White Cypress Pine, *Callitris glaucophylla*, communities in south-eastern Australia, Dick Williams' Bogong High Plains investigations, David Melick's study of warm temperate rainforests in east Gippsland, and Terry Judd's study of invasive shrubs.

In 1975, Dr Truda Howard's fourth RSV paper on Australia's evergreen *Nothofagus cunninghamii* was published and Dr David Ashton investigated mixed evergreen-deciduous *Nothofagus* forests in South America. He attended the Thirteenth Pacific Science Congress at the University of British Columbia in Vancouver in August 1975 and visited plant communities along the mountainous spine of North and South America from the Arctic to Tierra del Fuego. With massive wood-chip operations in the Chilean Andes imminent, he began collaborative ecological studies of their montane forests of *Nothofagus*.

The seminal 1981 publication, *Australian Vegetation*, carries Ashton's chapter on tall open-forests between Malcolm Gill's chapter on eucalypt open-forests and Truda Howard's on southern closed-forests.

Ashton's nine papers in the RSV *Proceedings* across four decades include 'Botany of East Gippsland' presented to the RSV Symposium on East Gippsland in 1967, and papers on Macquarie Island grassland and feldmark, the Big Ash forest at Wallaby Creek and nearby eucalypt forests, Westernport Bay's Pelican Island and tree fern communities, and plant ecology of the southern Brisbane Ranges. Some were co-authored with current or former research students, Malcolm Gill, Truda Howard, Dick Williams and Neville Scarlett. Ashton's 1999 Pelican Island paper describes the McCoy Society's last

Fig. 3. David Ashton and the Botany III ecology excursion to Mt Towrong (near Mt Macedon) in March 1969 — lunchbreak (John Jenkin photo).

project, which began with a vegetation survey by a large contingent from the Botany School in 1992.

Retiring as reader in 1989, Dr Ashton became an Honorary Associate of the University of Melbourne's Botany School and an Honorary Research Fellow in La Trobe University's Botany Department, where he was welcomed with open arms and a room. He continued ecological research while serving on various advisory bodies, including the Australian Heritage Commission's Victorian Natural Environment Evaluation Panel, the Victorian National Parks Advisory Council, Wilsons Promontory Advisory Group and Parks Victoria's Alpine Ecology Scientific Review Panel.

Post-retirement awards and honours began with the prestigious Medal of the Ecological Society of Australia in 1990. In 1999 he was doubly honoured. Victoria's Department of Natural Resources and Environment established the David Ashton Biodiversity Award for departmental staff for scientific achievements which enhance the understanding, conservation or management of Victoria's biodiversity. Rangers at the Kinglake National Park, which then included the Big Ash forest, organised a celebration for his research jubilee with the unveiling of a bronze commemorative plaque at Wallaby Creek. Since this is still part of Melbourne's water catchment and therefore inaccessible to the public, the plaque was erected at the Toorourrong Reservoir Park, in sight of the forests David Ashton knew so well. In 2000 he received a Parks Victoria Kookaburra Award for his contributions to Victoria's parks, in 2001 a medal of the Order of Australia for services to plant science, and in 2002 a University of Melbourne DSc degree for his published work.

Despite poor health, Dr Ashton prepared three extensive papers on his half-century's scientific scrutiny of the mighty Mountain Ash, including 'The environment and plant ecology of the Hume Range, central Victoria', which was published in the RSV *Proceedings* in 2000. It concludes

> Any management demands a detailed knowledge of synecology and autecology of the major species. Long term observations remain essential prerequisites for gaining ecological perspective. Adequate conservation not only requires that we know what we want to conserve but also where, how and why. To date, this task in many areas has only just begun.

David Ashton was an artist, poet, pianist and composer, as well as ecologist. Warm, generous and modest, he devoted his professional life to an ecological exploration of plant communities and marvelled at the beauty as well as the science of the living landscape. With his students, he attempted to understand the ecological interactions which sustain plant communities. He is survived by ecosystems which he and his students investigated; by his landscape paintings; by his published papers, which provide foundations for intelligent conservation and management decisions; by the ideas and practices of his postgraduate students in CSIRO, national parks and forestry, universities and schools; and by the 'David Ashton Biodiversity Award' to encourage the conservation of Victoria's biodiversity. As Dr John Jenkin remarked, he 'was a 'one-off'; we may never see his like again'.

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Burnett, Pacific Science Association, Mary Ellis, Wilsons Promontory Advisory Group, Peter Jacobs, Kate Millar, Marie Keatley, Neil McCarthy and Ion Maher of Parks Victoria, Michael Howes of the Victorian National Parks Association, John Morgan and Bob Parsons of La Trobe University, Ashton's former research students, Judy Frankenberg, Truda Straede née Howard, Malcolm Gill (CSIRO), John Jenkin (Deakin University), Rowan Webb (UNE) and Pauline Ladiges (University of Melbourne) and his former colleague, Ray Specht. During my historical investigation of the University of Melbourne's Botany School, David Ashton discussed his teaching and research. Mark Richmond and Jason Benjamin provided information from the University of Melbourne Archives. The University of Melbourne's annual *Calendar* and *Research Report* yielded other information. The select bibliography of Ashton's papers in five journals covered by the Web of Science reveals his research collaborators and the scope of his research interests.

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